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Installation effects in ultrasonic gas flow meters

Calibration results of a Z-configuration measurement skid

Dave van Woensel
08 June 2017

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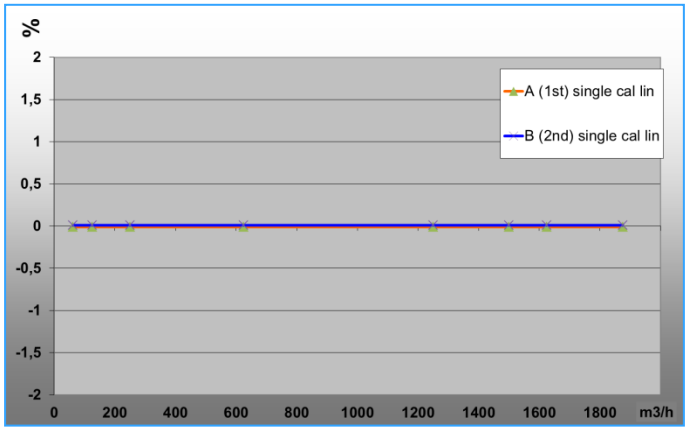
1. **Installation Effects**
2. Skid Calibration
3. Results

Ultrasonic flowmeter for Custody Transfer

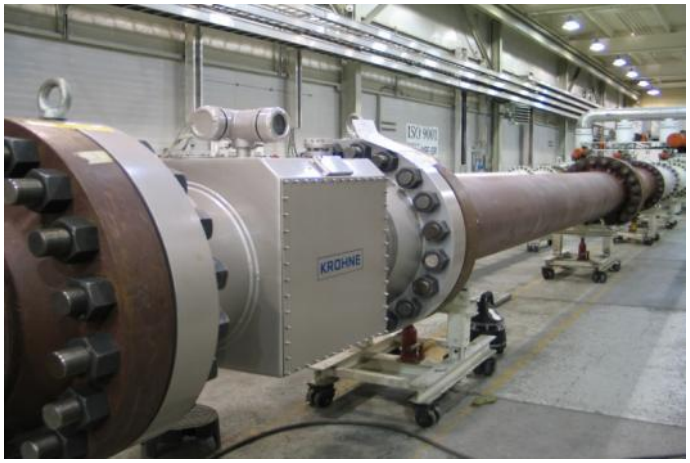
Agenda

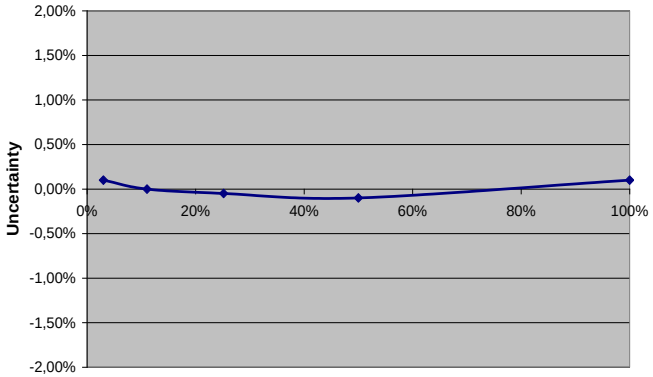
Customer request

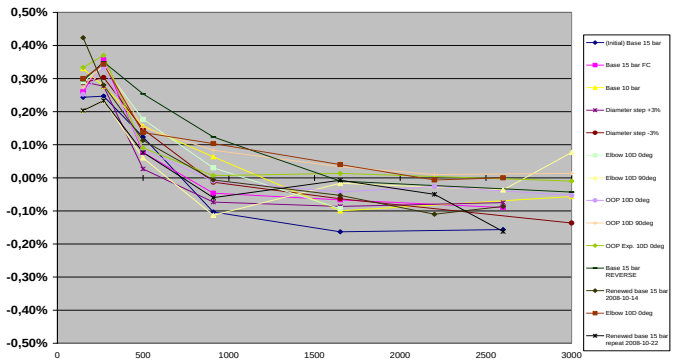
Will the meter measure as accurate as calibrated once assembled on the skid?



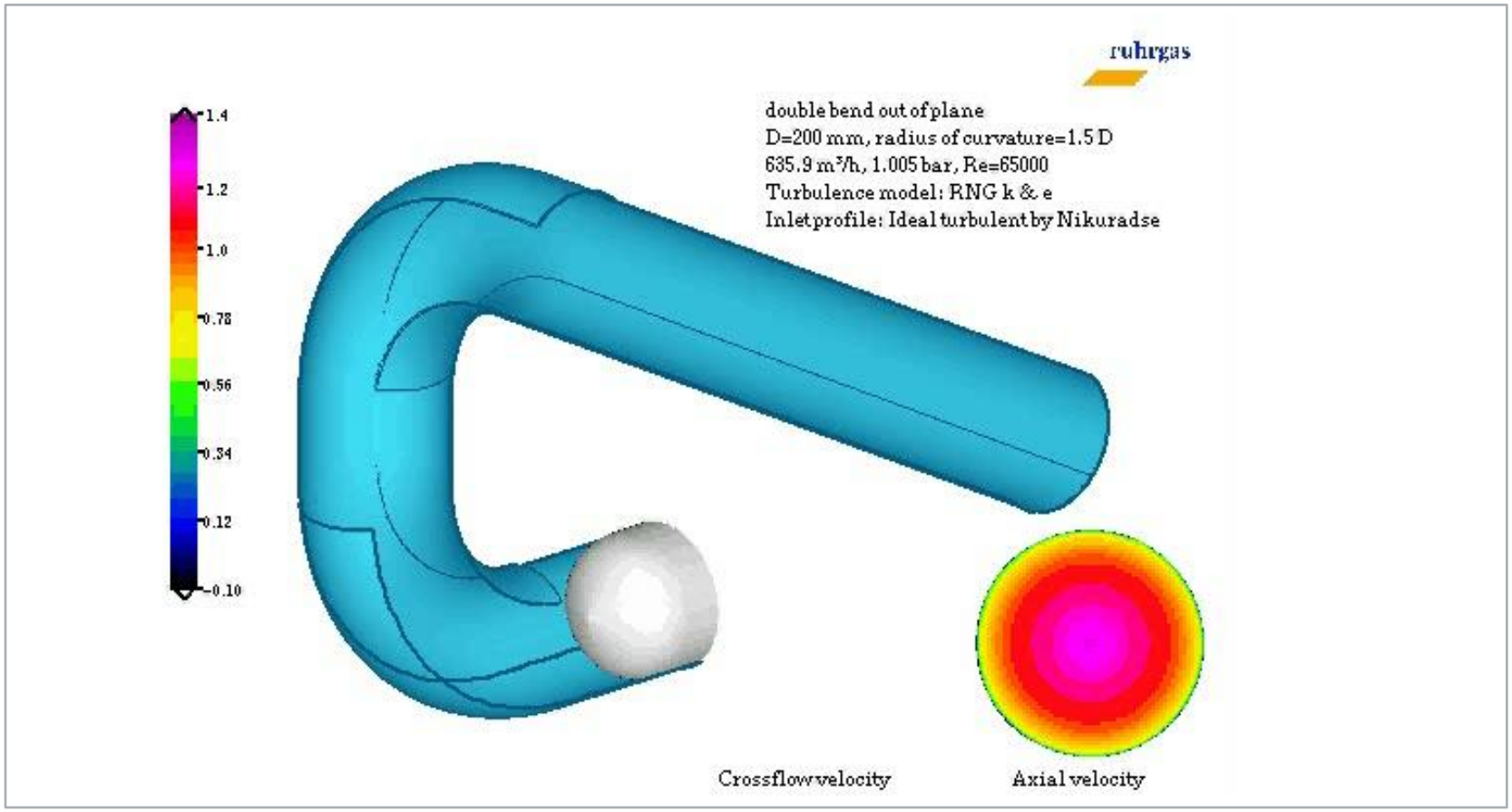
Installation effects





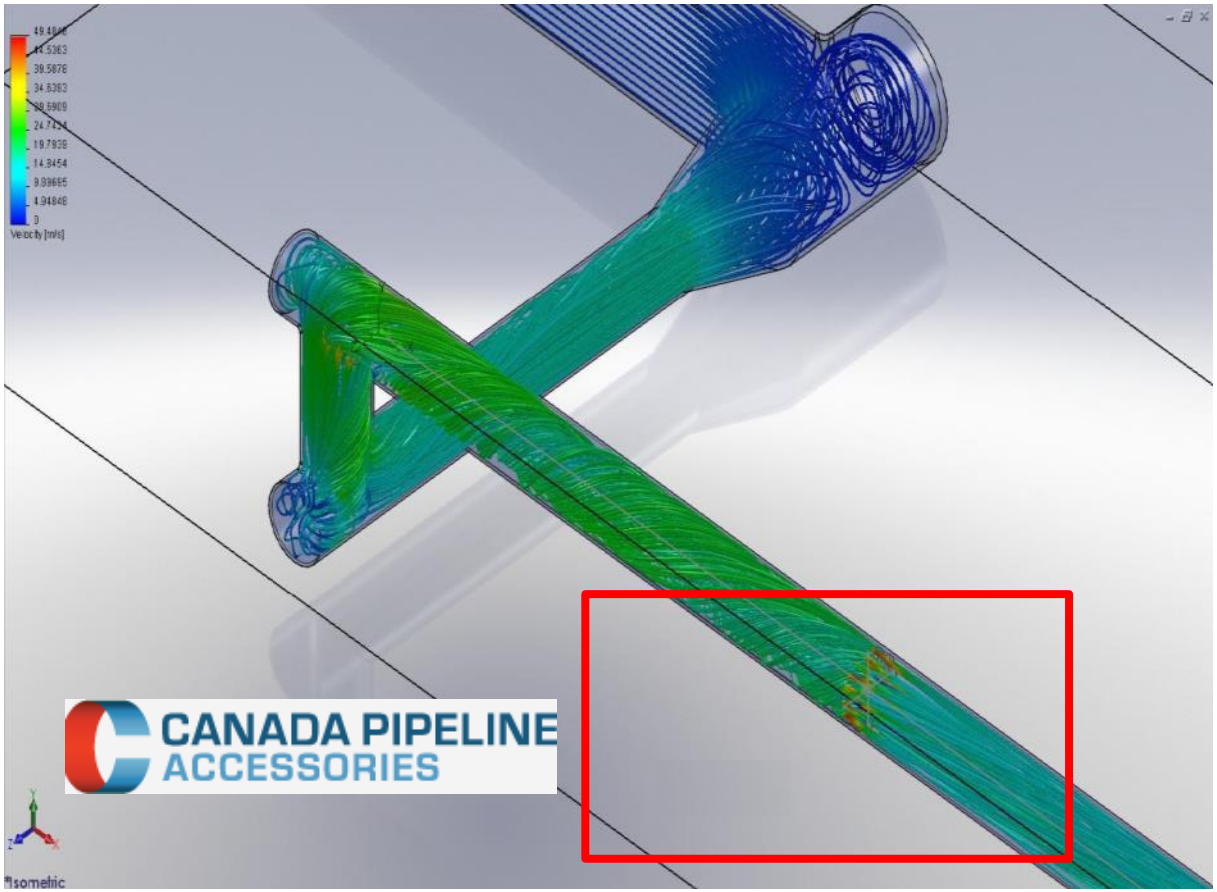


Swirl

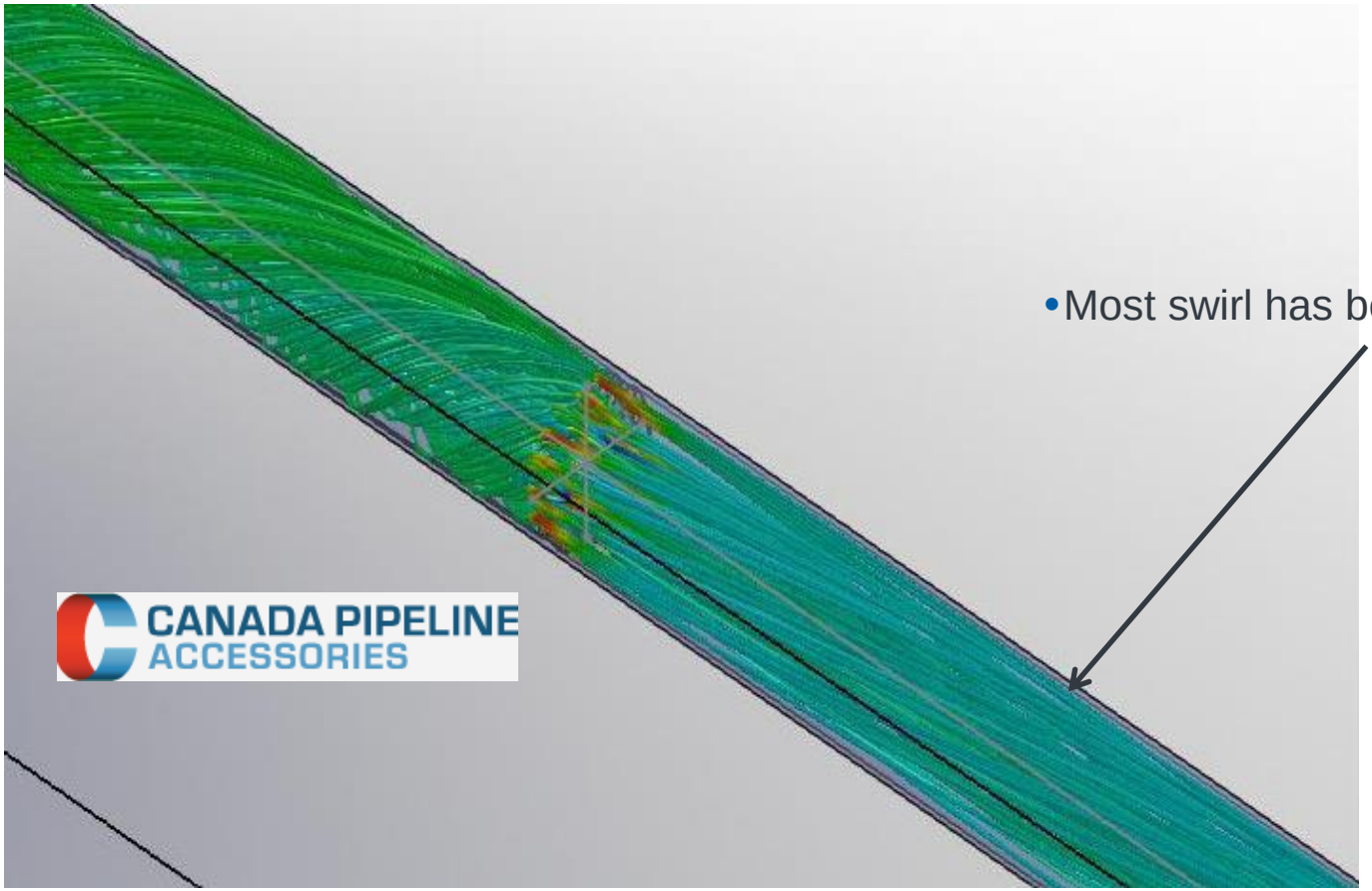

ruhrgas
double bend out of plane
D=200 mm, radius of curvature=1.5 D
635.9 m³/h, 1.005 bar, Re=65000
Turbulence model: RNG k & e
Inlet profile: Ideal turbulent by Nikuradse
1.4
1.2
1.0
0.78
0.56
0.34
0.12
-0.10
Crossflow velocity
Axial velocity

Swirl and flow conditioning

Computational Fluid Dynamics (CFD)

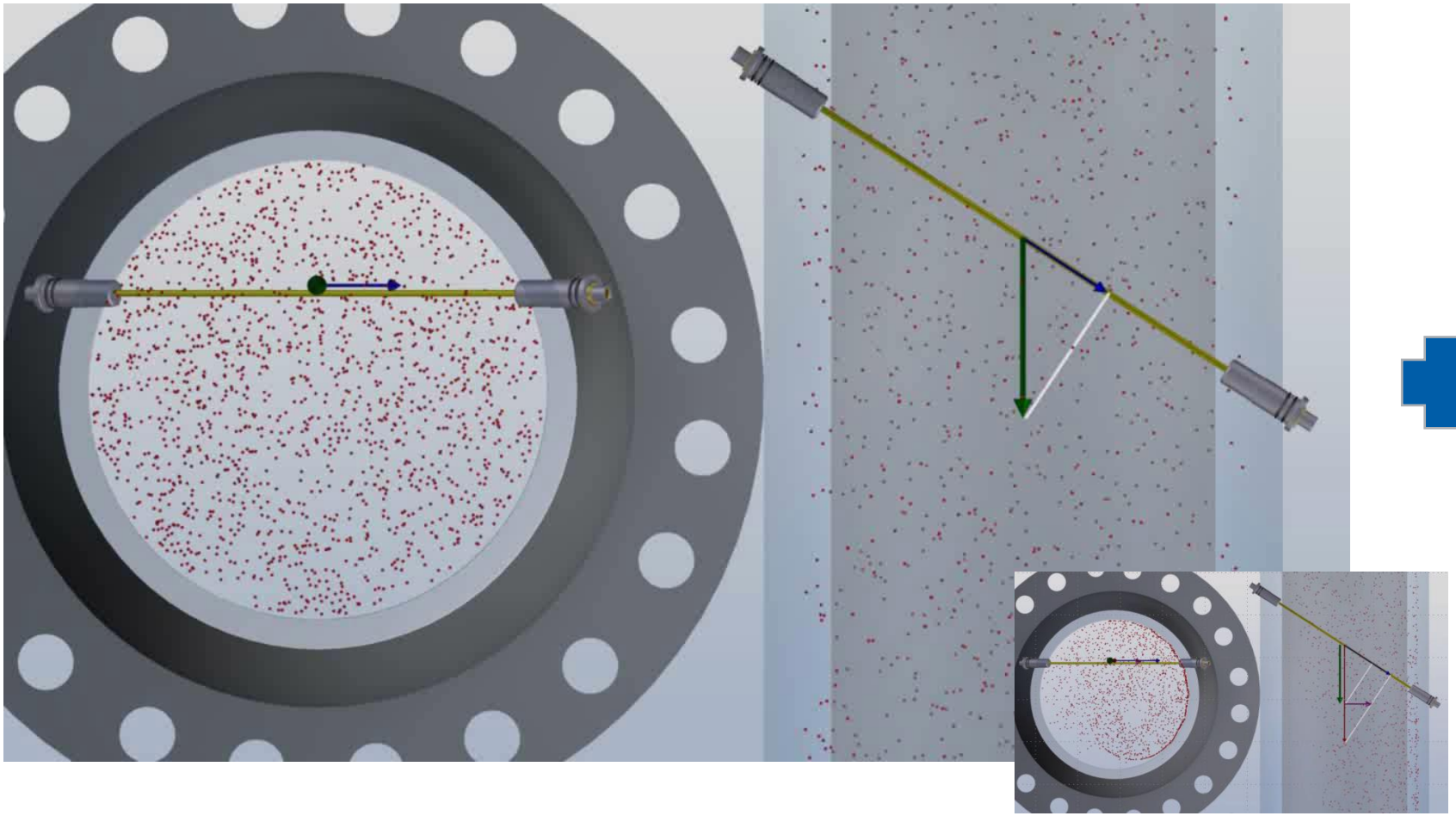


Remaining swirl after flow conditioner

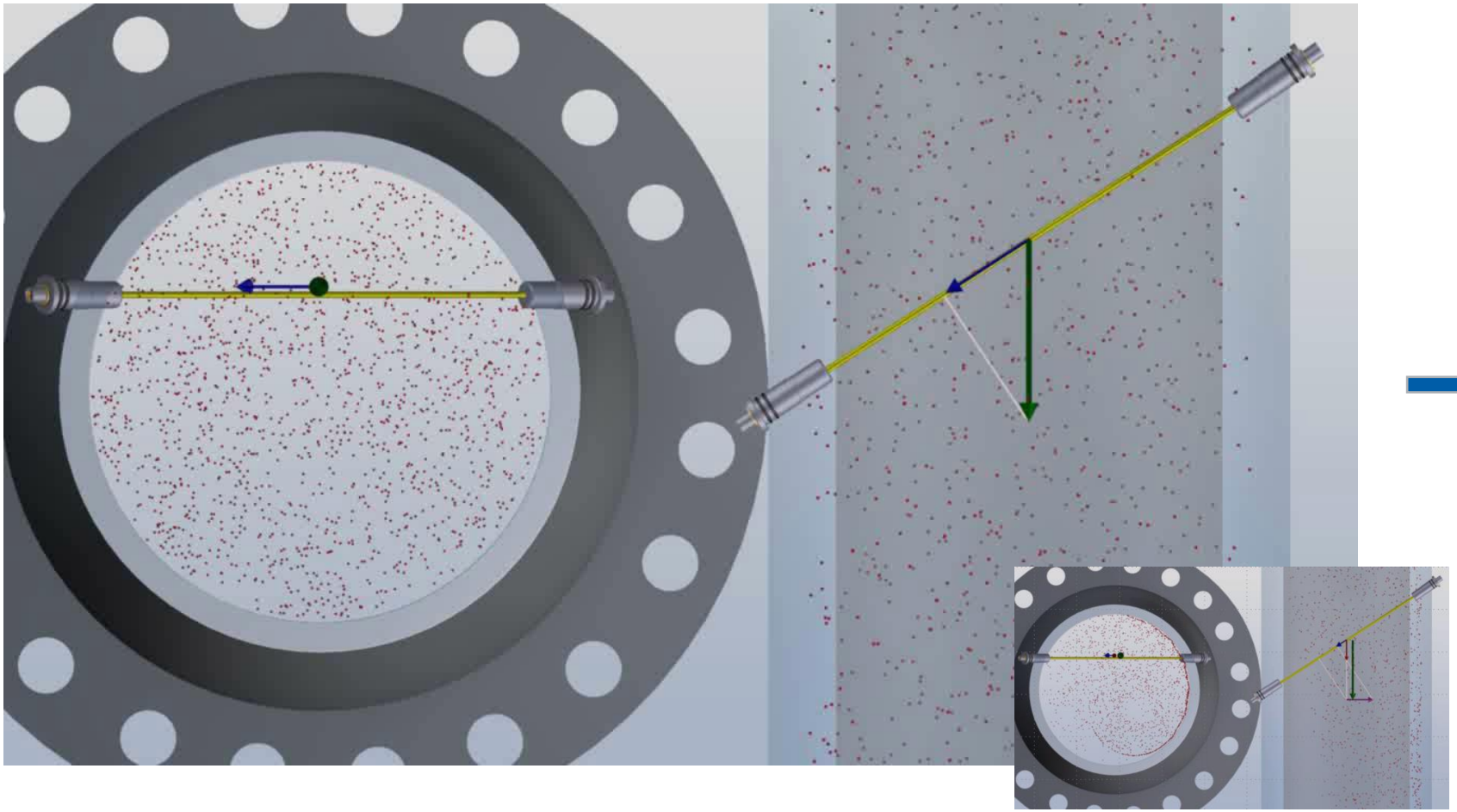


- Most swirl has been removed

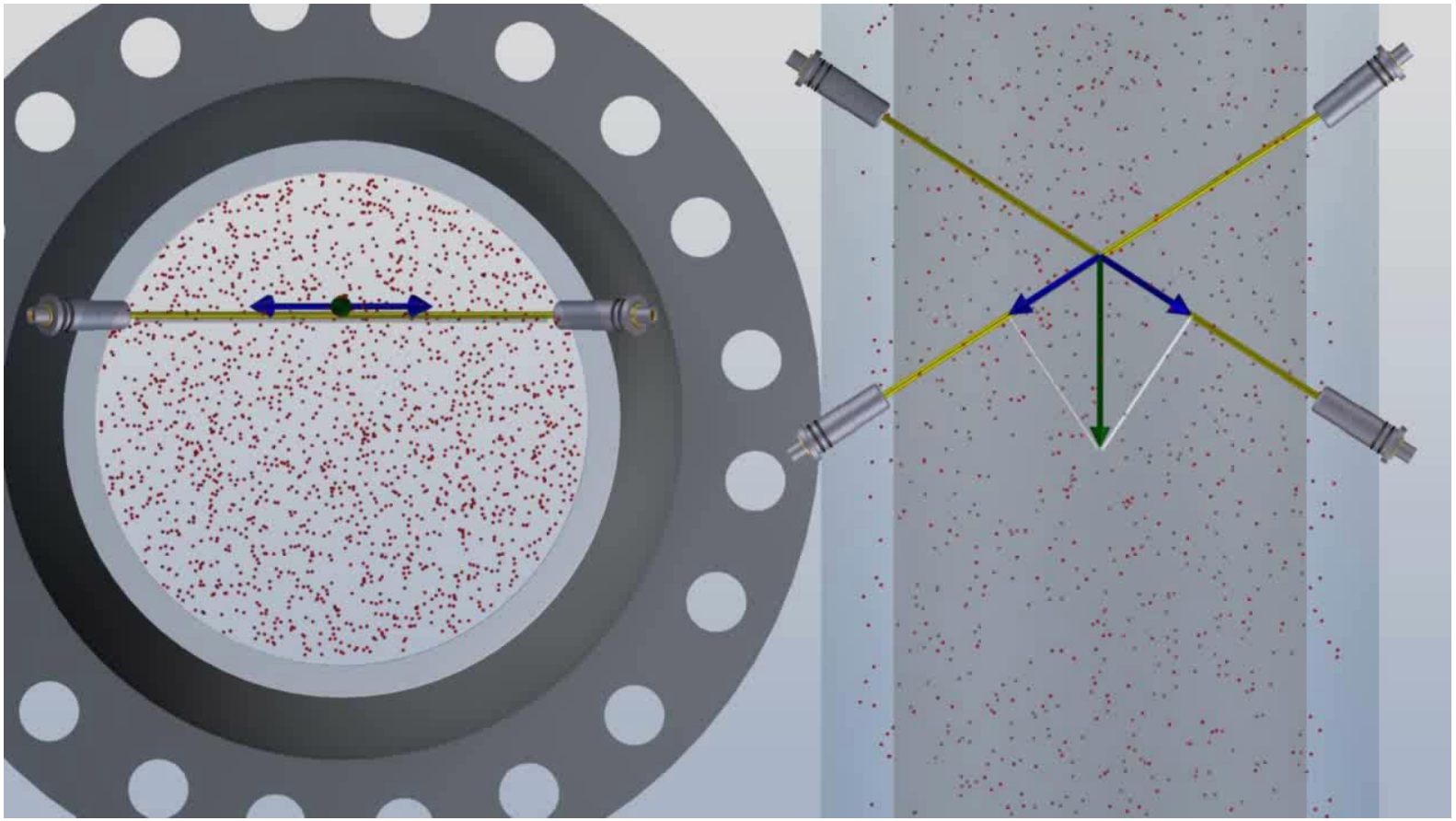
Swirl causing meter to overread



Swirl causing meter to underread



Swirl compensation in plane



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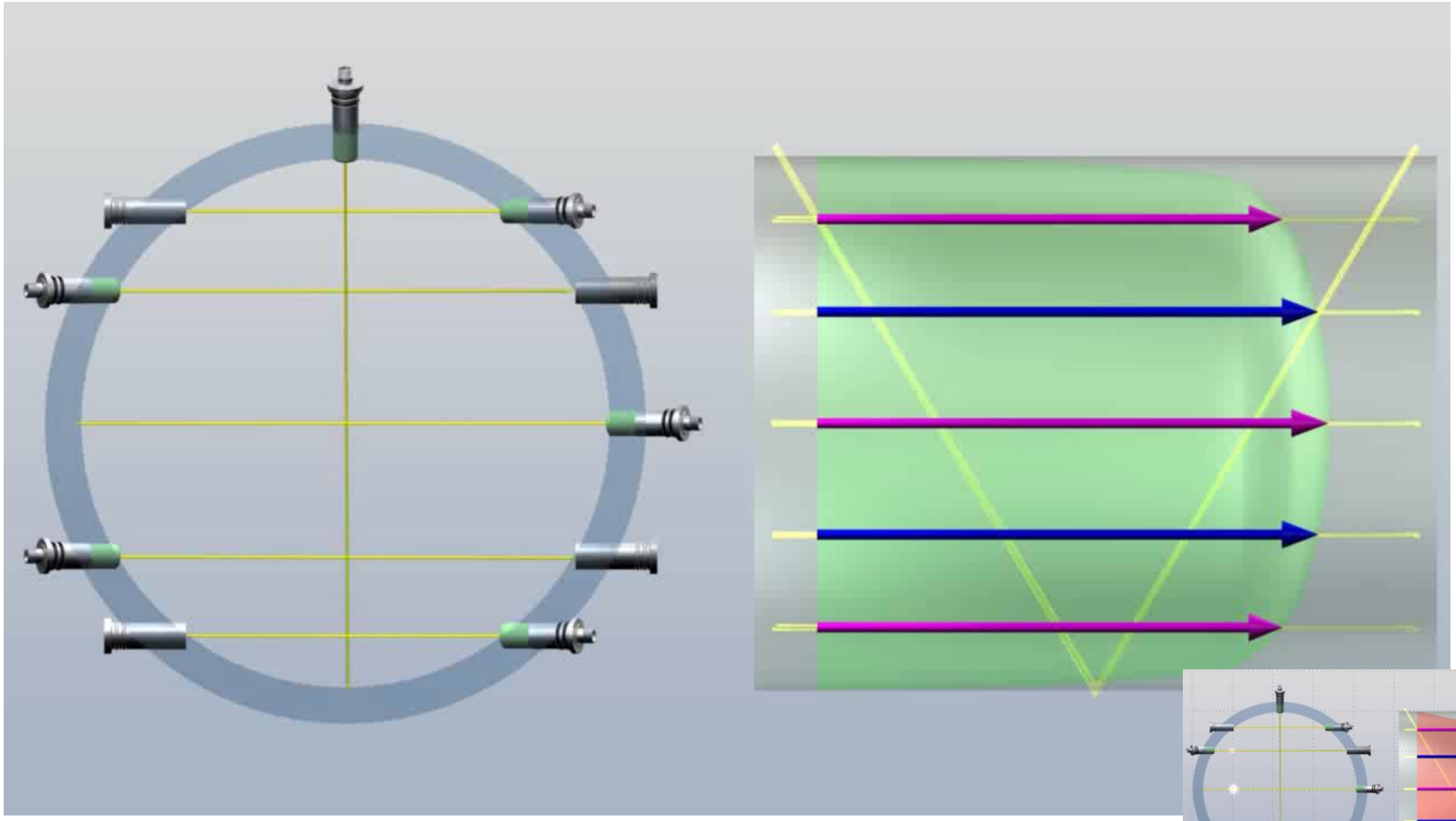
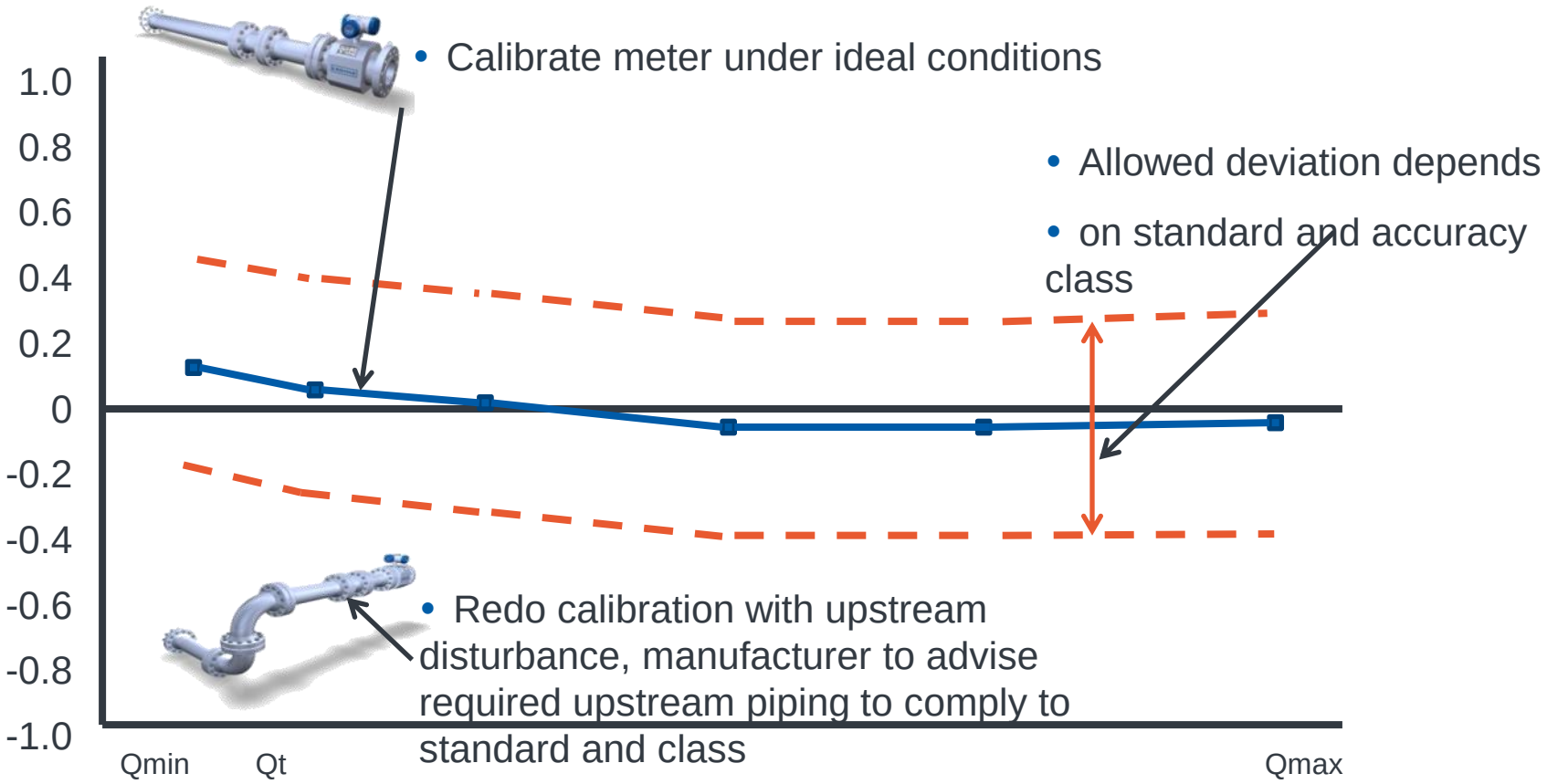
Multiple paths for flow profile recognition



How standards describe installation effects



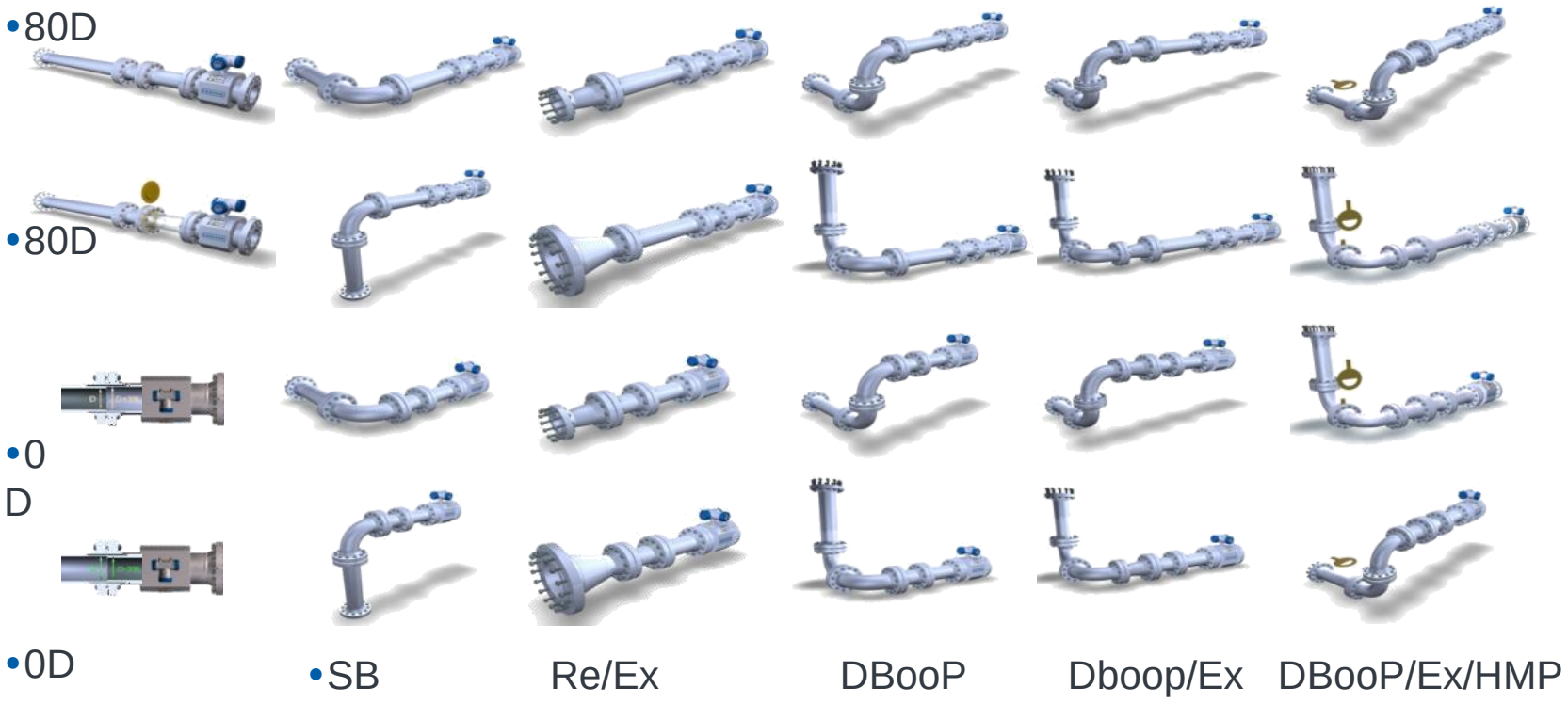
Allowed deviations due to installation effects

OIML R137 class 1	OIML R137 class 0.5	AGA 9	ISO 17089
± 0.33% (1/3th of class)	± 0.17% (1/3th of class)	± 0.3%	± 0.3%

- Perturbation testing is done during one-off type test
- Uncertainty due to installation effect comes on top of regular calibration result (installation effects are not seen during a regular calibration)
- OIML certificates are issued by an independent 3rd party (e.g. NMi, PTB).
- AGA9 and ISO 17089 compliance is not checked by 3rd party.

Example of perturbation tests

ISO 17089 and OIML R137-1 requirement shown below



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1. Installation Effects
2. **Skid Calibration**
3. Results

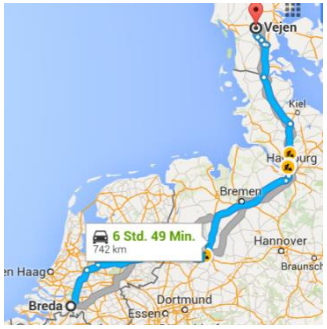
Ultrasonic flowmeter for Custody Transfer

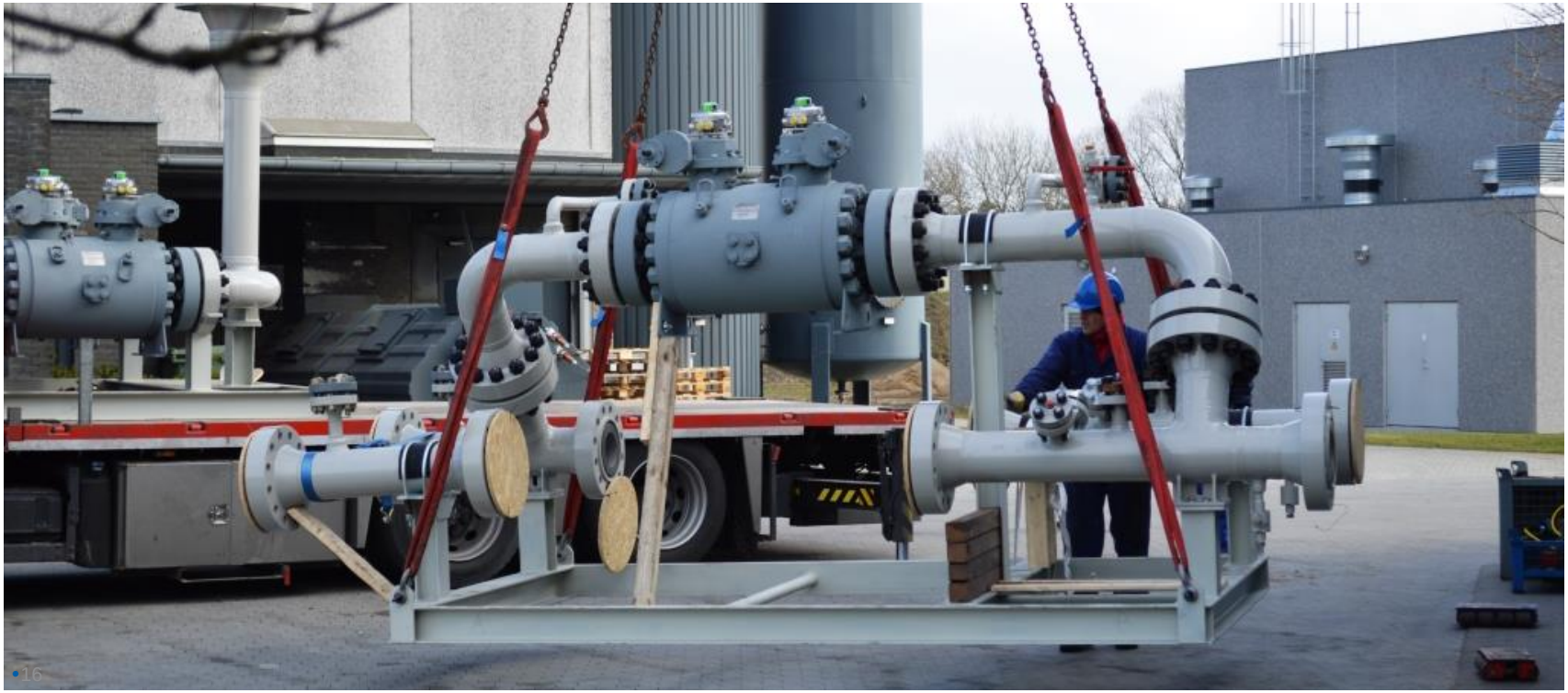
Agenda

Customer concern

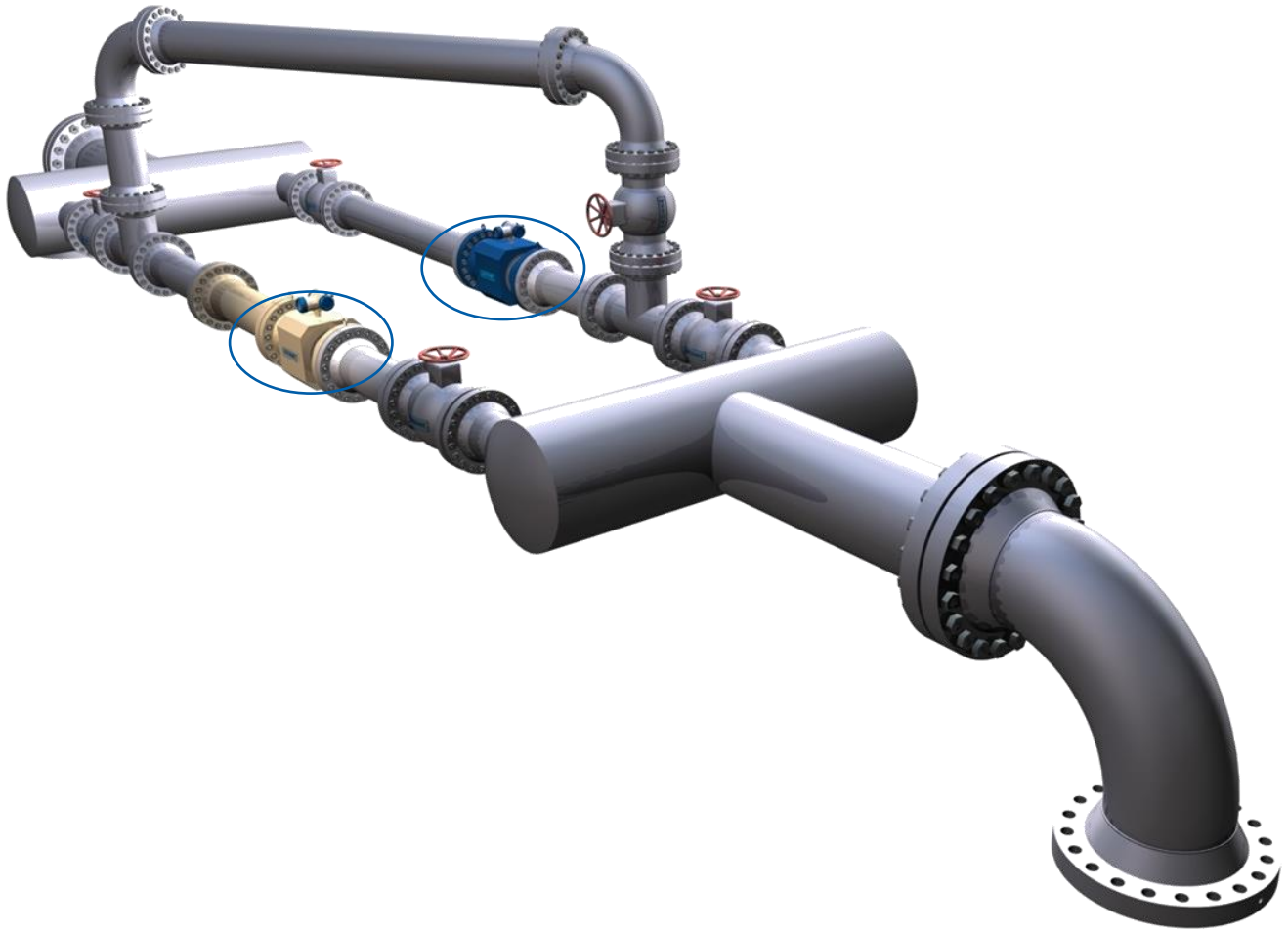
Will the meter measure as accurate as calibrated once assembled on the skid?

→ The only way to find out is to calibrate the entire skid

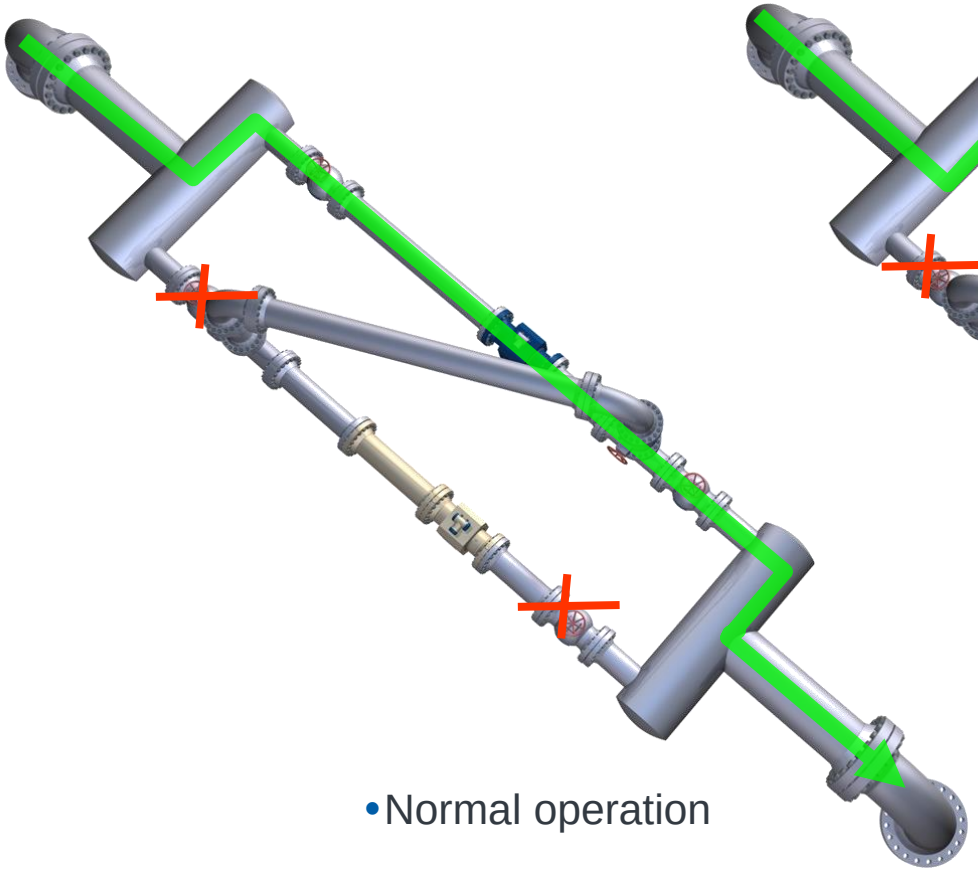




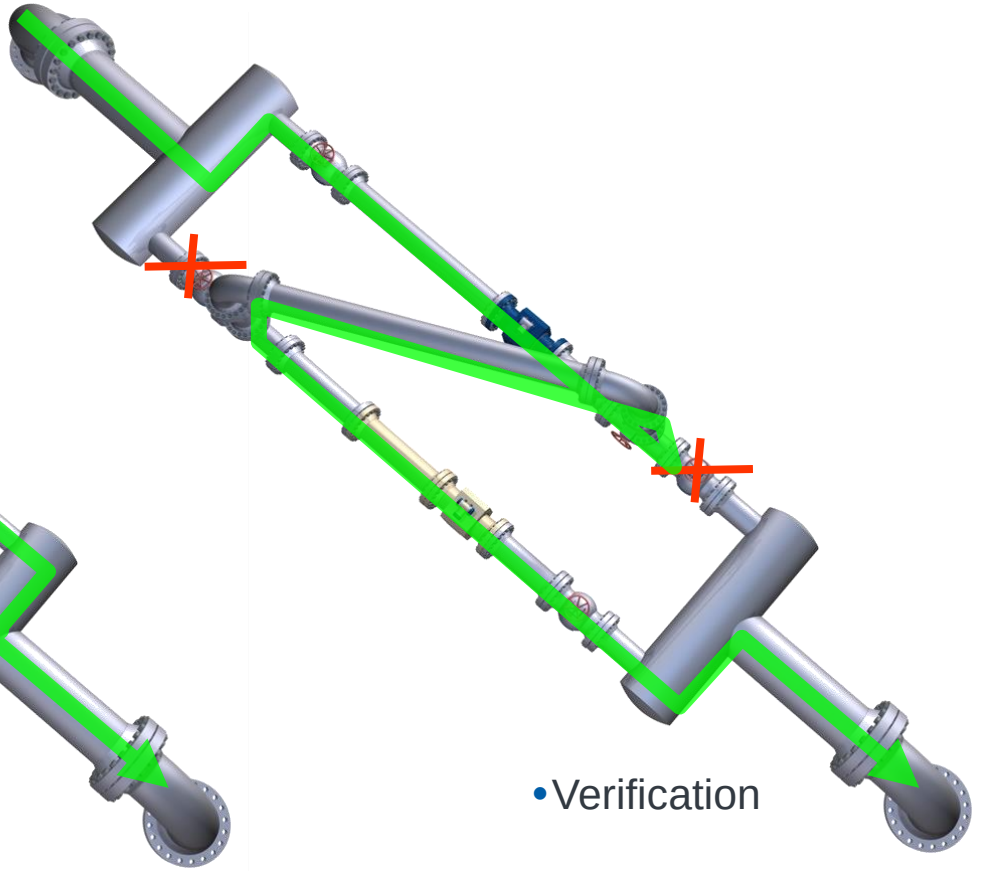
Flow measurement skid required by customer



Flow measurement skid

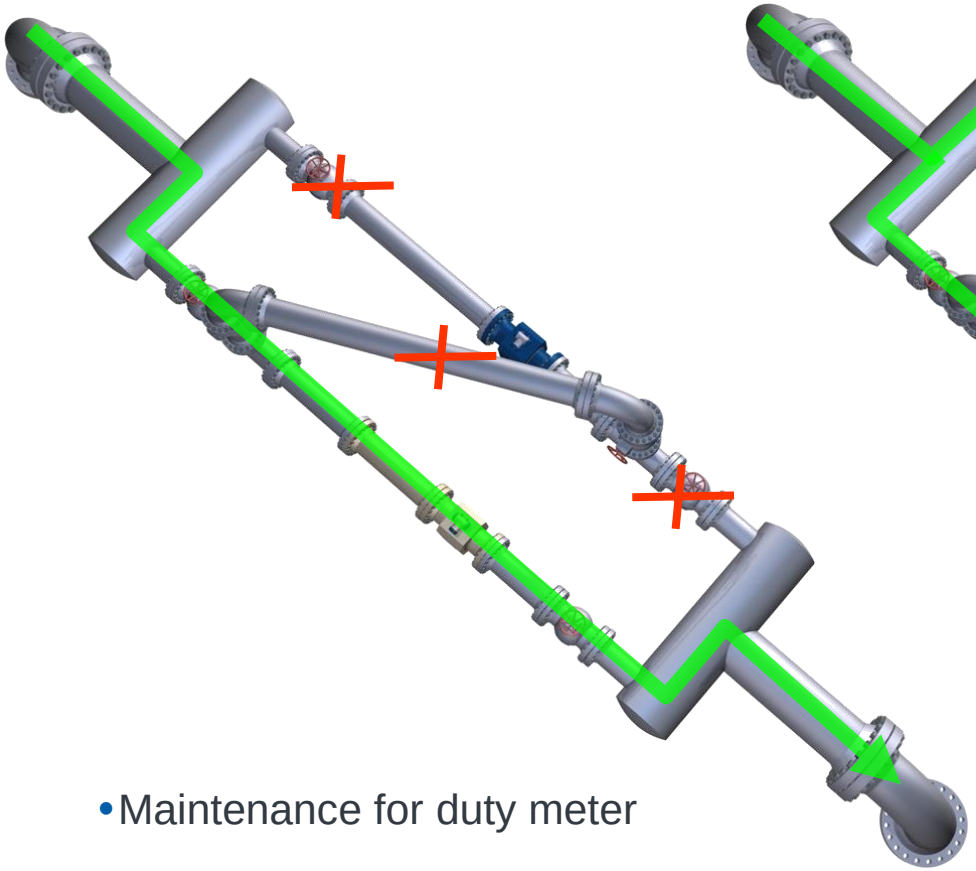


- Normal operation

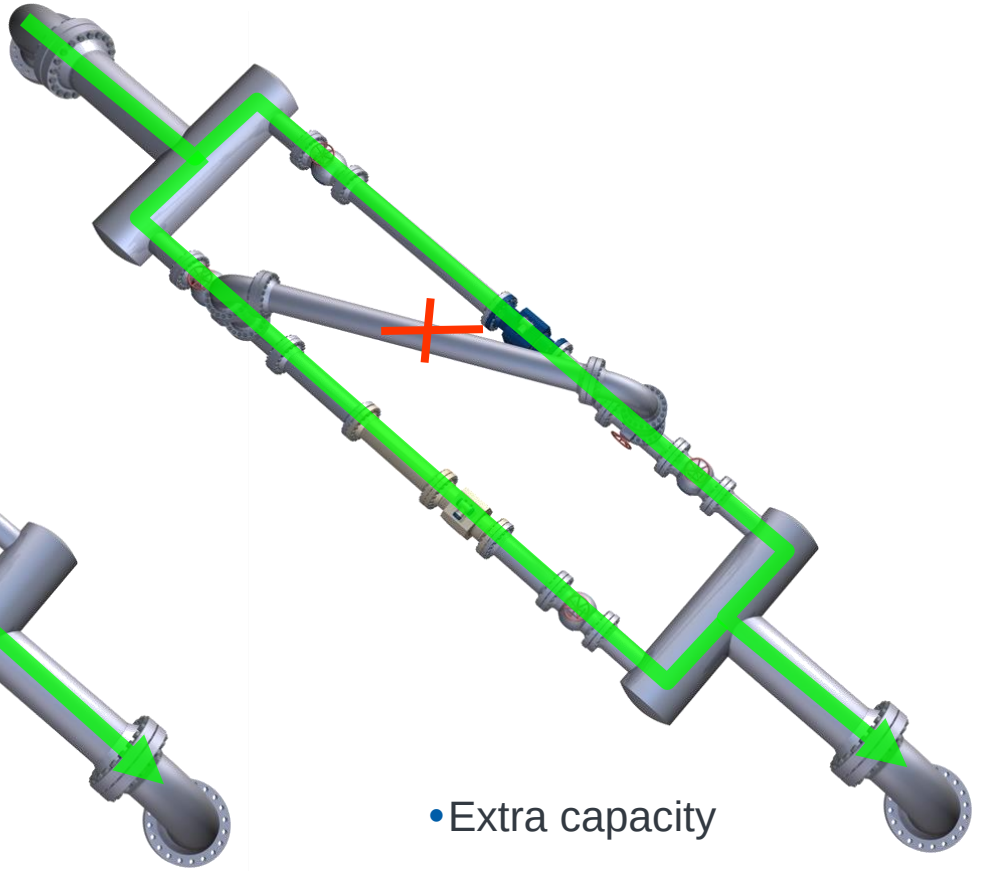


- Verification

Flow measurement skid



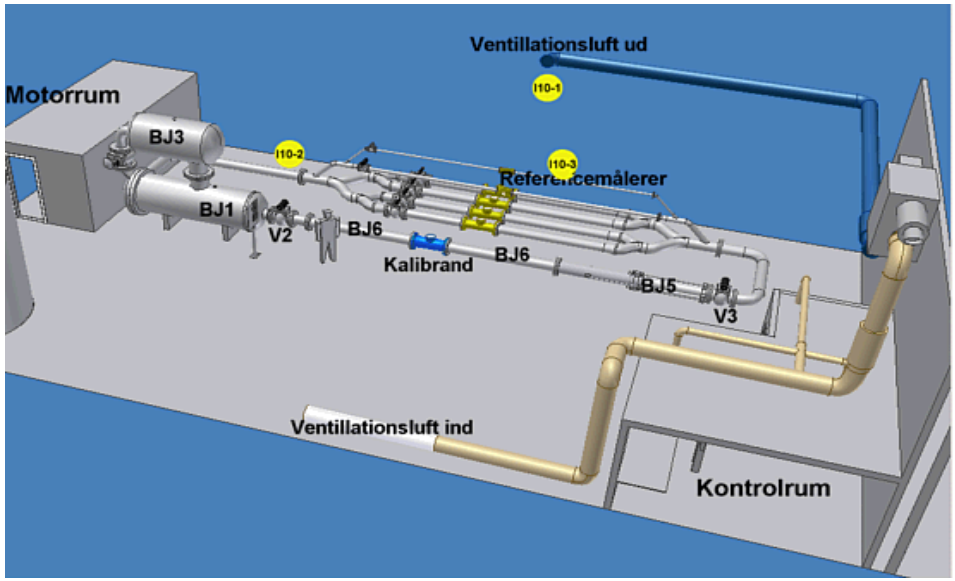
- Maintenance for duty meter



- Extra capacity

Force Technology small calibration loop

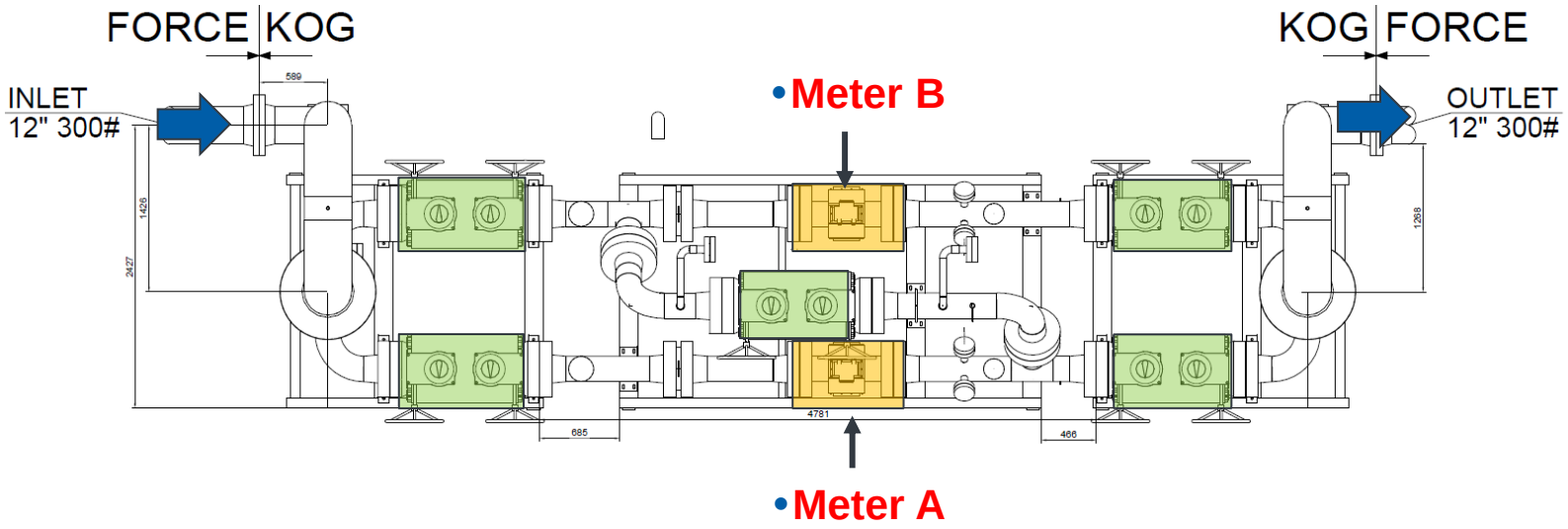
- Flowrates 8 -10,000 m3/h
- Calibration pressure 0 - 50 barg
- Lab uncertainty 0.18 - 0.30



Skid calibration (2x 8”/1500#)

Skid calibrated at FORCE (Denmark)

Skid calibration (2x 8”/1500#)



- Calibration pressure 50 bar
- Flow rates loose meter calibration 62 m3/h (0,8 m/s) – 2500 m3/h (31,3 m/s)
- Flow rates skid calibration 62 m3/h (0,8 m/s) – 1875 m3/h (23,4 m/s)

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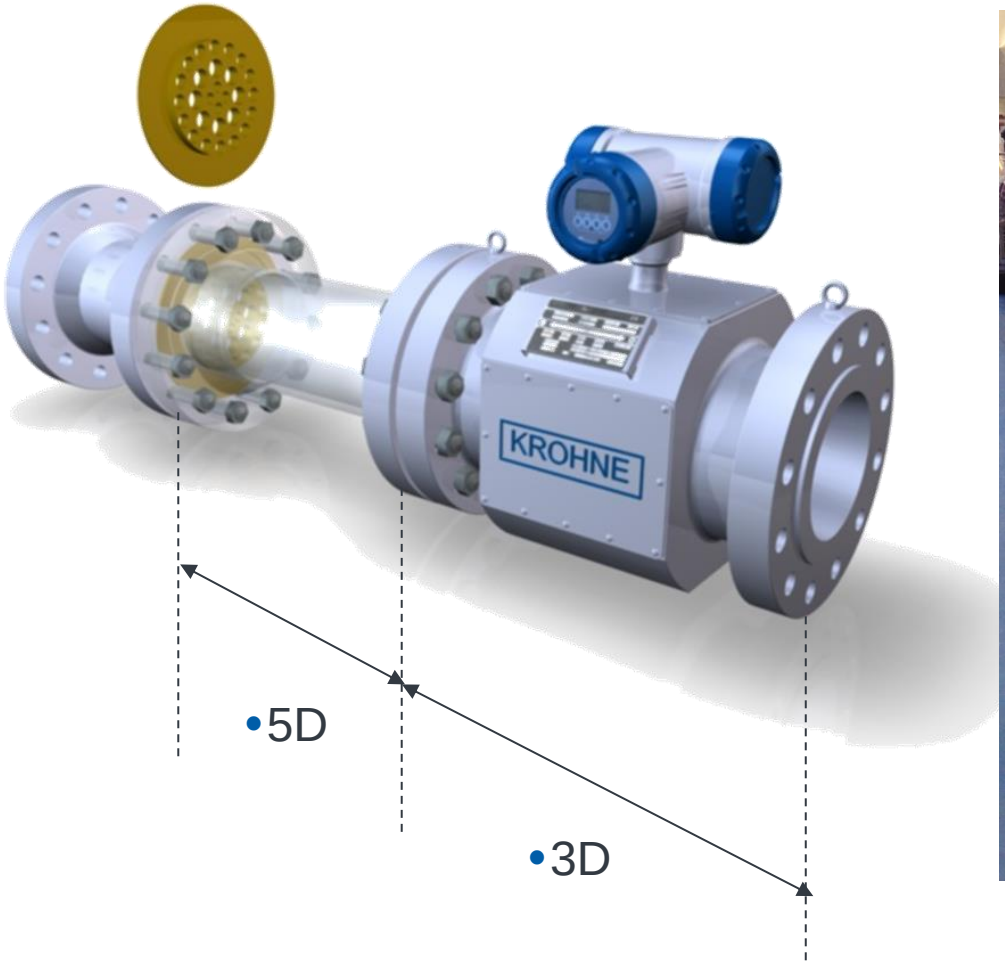
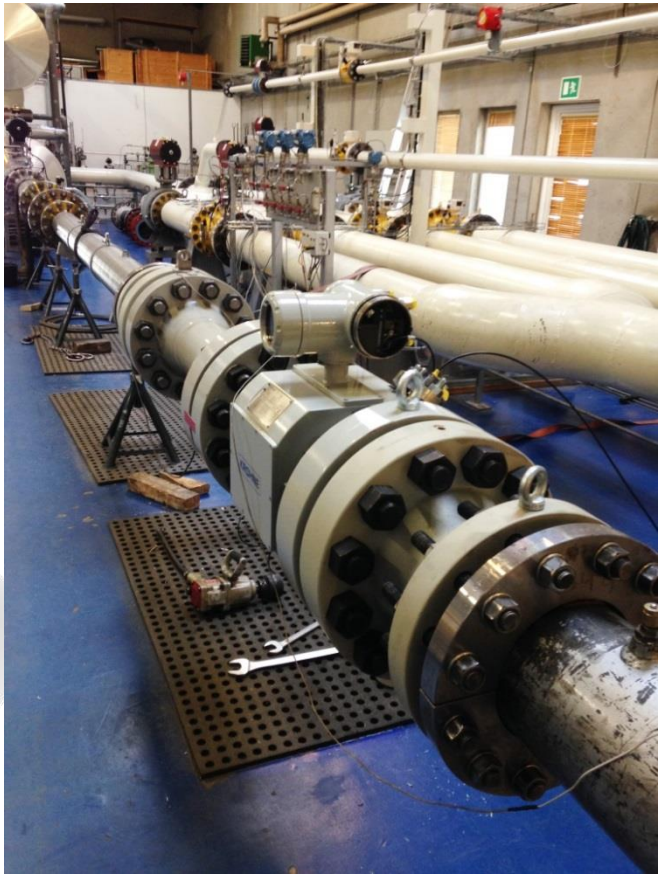
3. **Results**

Ultrasonic flowmeter for Custody Transfer

Agenda

Calibration of loose meters



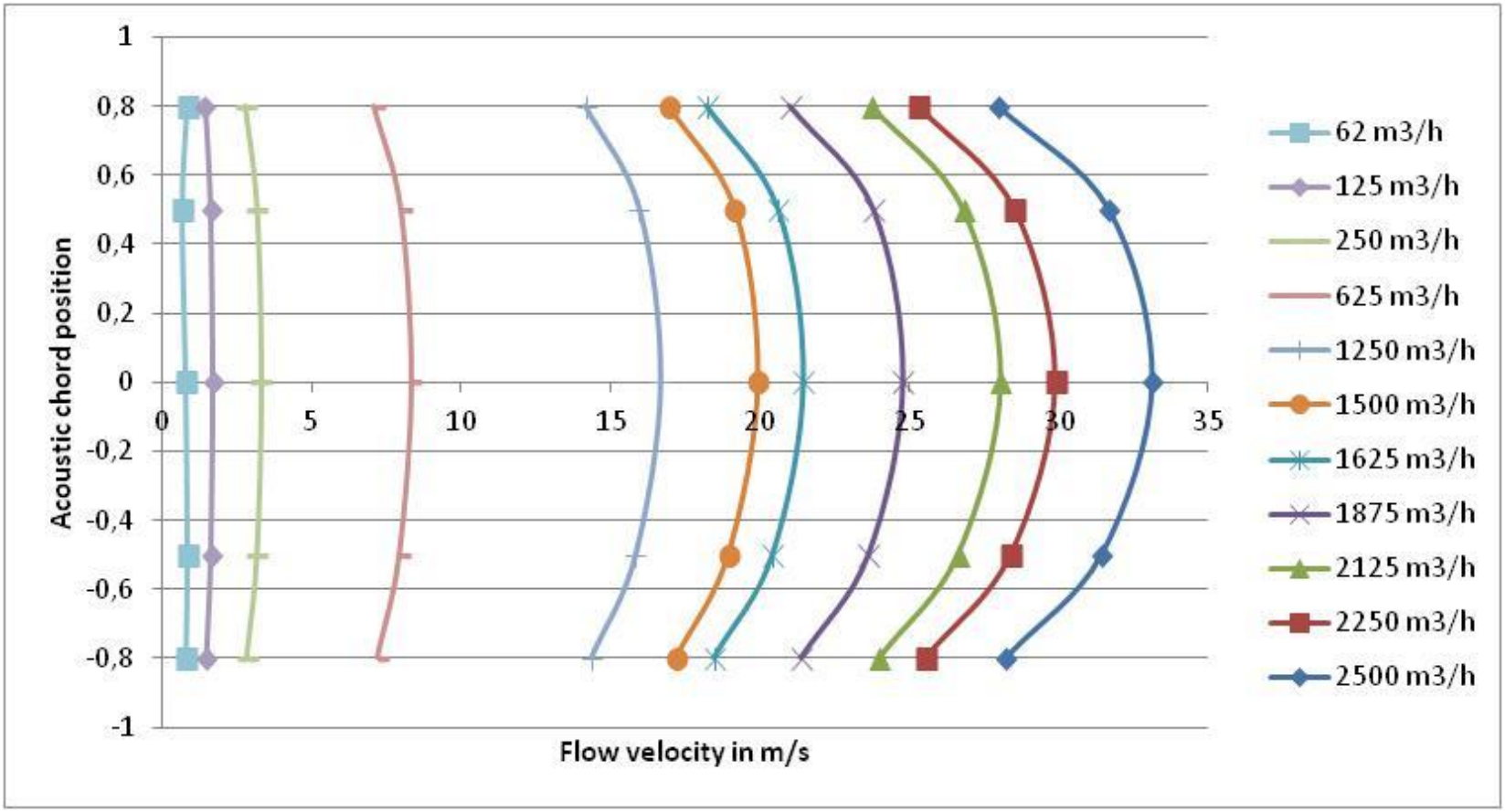


Flow conditioner and upstream piping

- KROHNE Flowcon3 (modified Spearmann plate), position locked by bracket
- Inlet pipe permanently affixed to flow meter
- This is not normal procedure but specifically done for this project

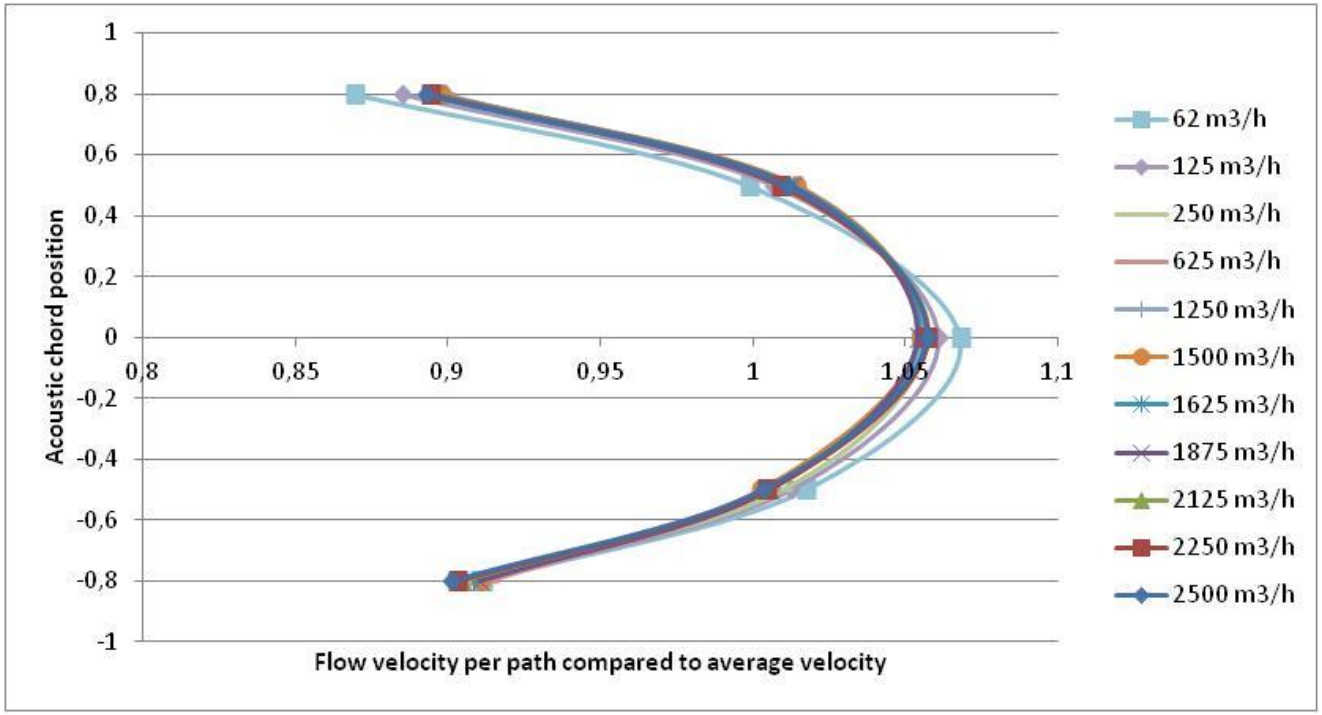
Flow profiles at different flow rates

Meter A, loose meter calibration



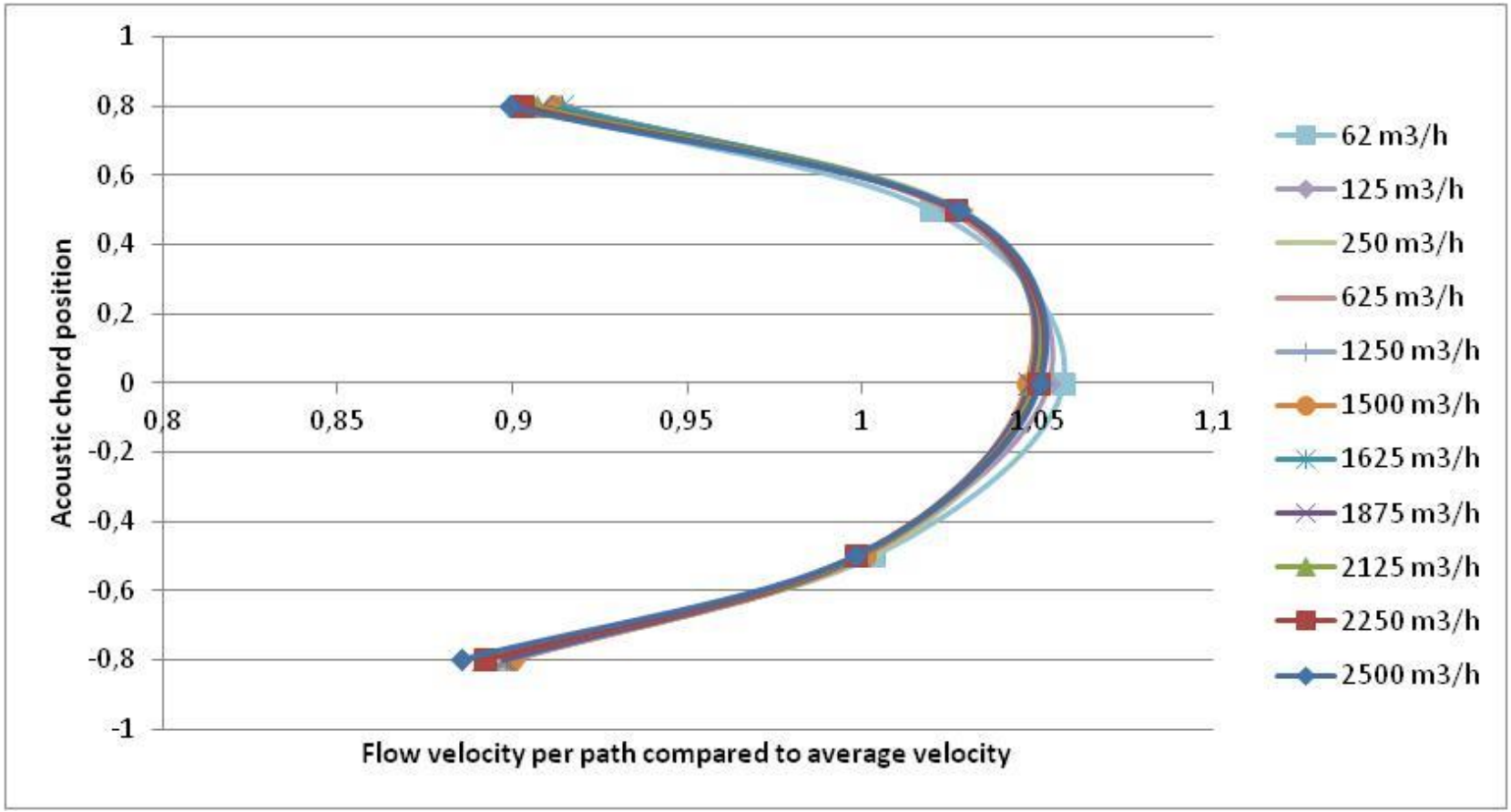
Flow profiles at different flow rates

Meter A, loose meter calibration



Flow profiles at different flow rates

Meter B, loose meter calibration

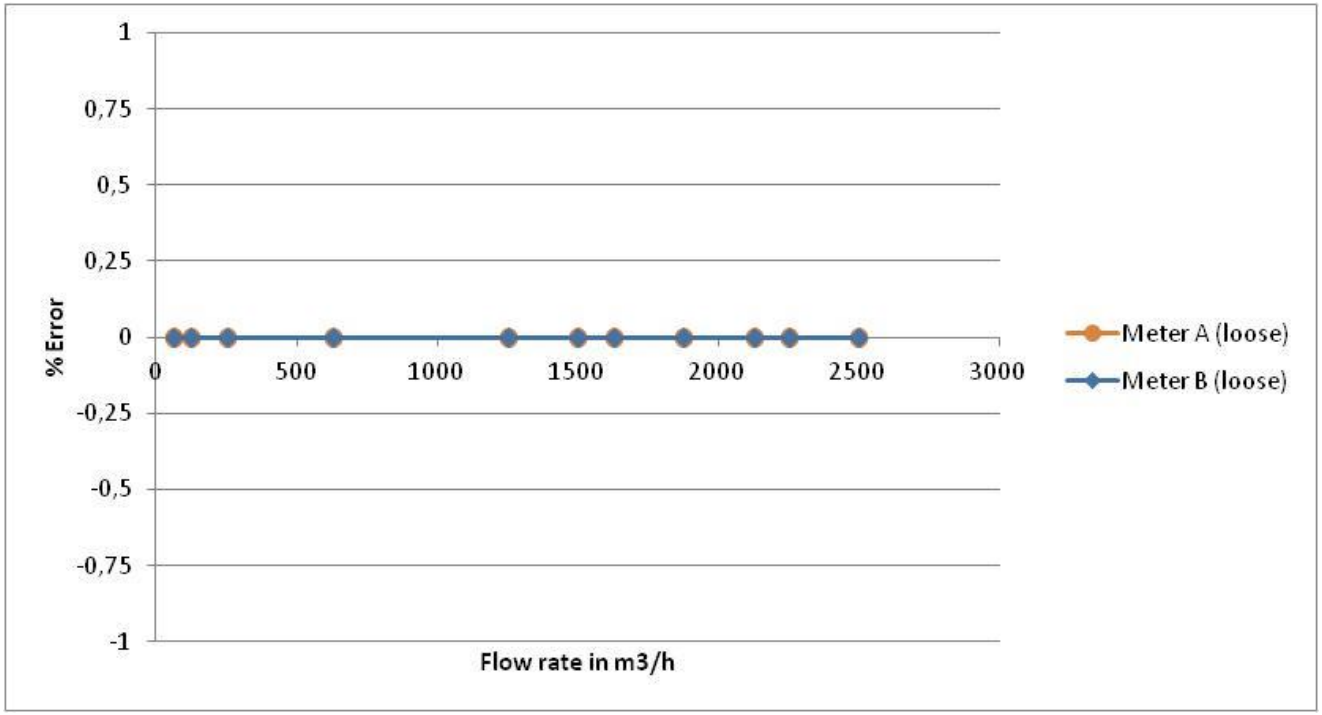


Modified flow conditioner to minimize noise production

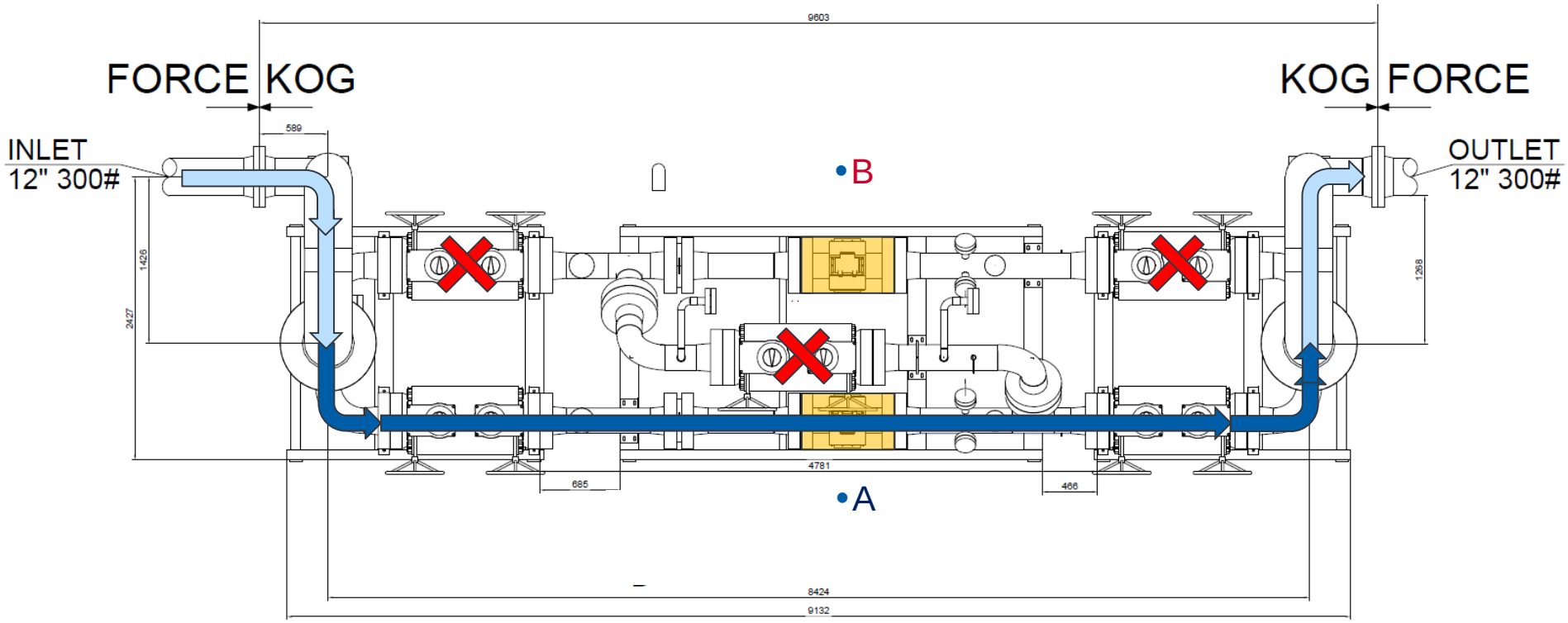
- Flow conditioner of meter B produced ultrasonic noise at flowrates ≥ 2200 m3/h.
- Flow conditioner modified to reduce noise production.
- After modification less noise and only starting at 2450 m3/h.
- Modifications caused flow profile of meter B to be slightly asymmetric (combination with upstream conditions).
- Noise production by flow conditioner occasionally happens and is a typical case of bad luck.

As left calibration results meter A and B

Baseline after linearization



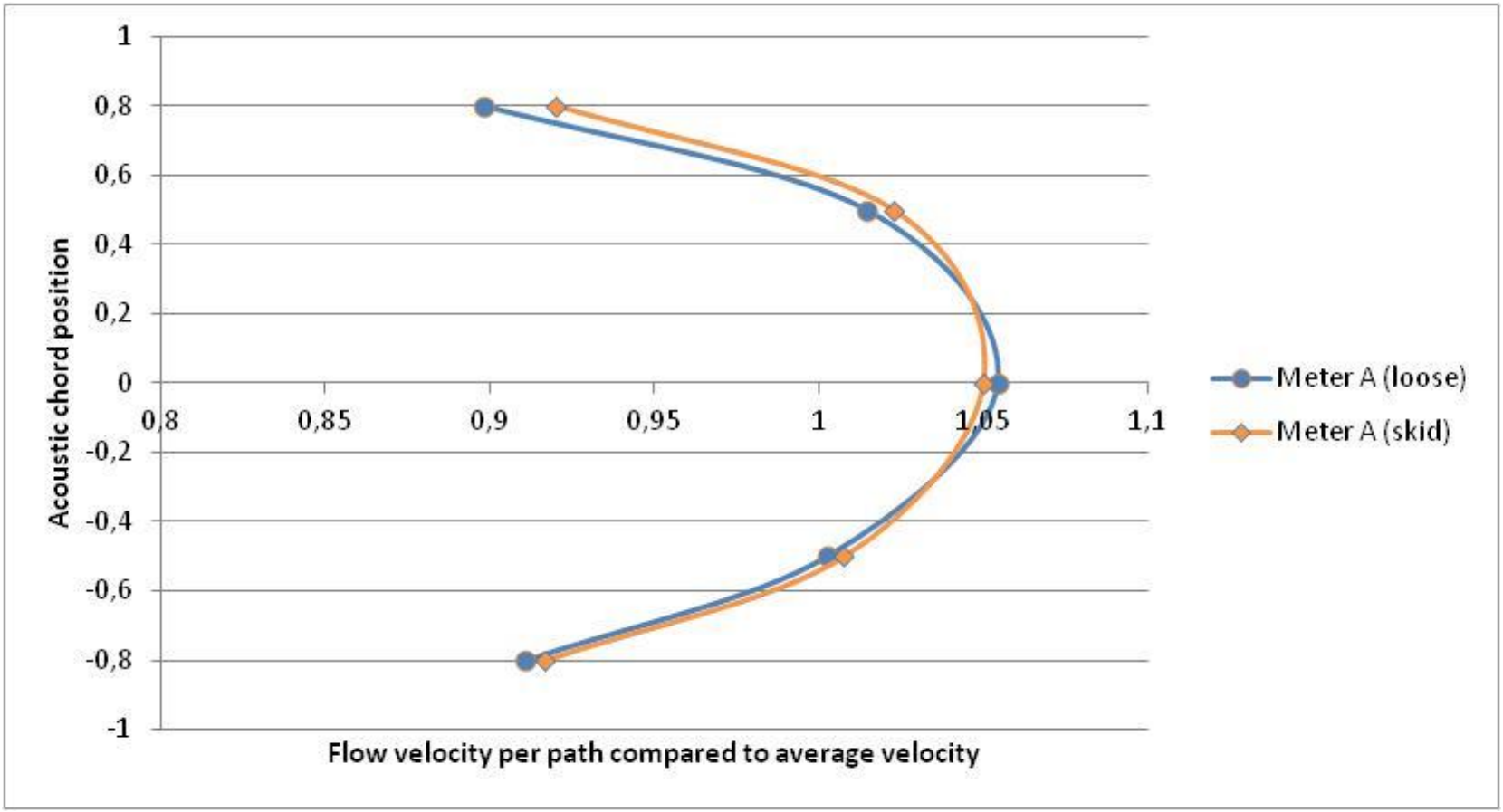
Calibration of meter A in skid



- Inlet conditions:
  - 3x 90° bend, 1x T-section, 1x 90° bend (all swirl generators)
  - 2 fully open ball valves, 6D straight
  - Flow conditioner, 5D straight (used in original meter calibration)

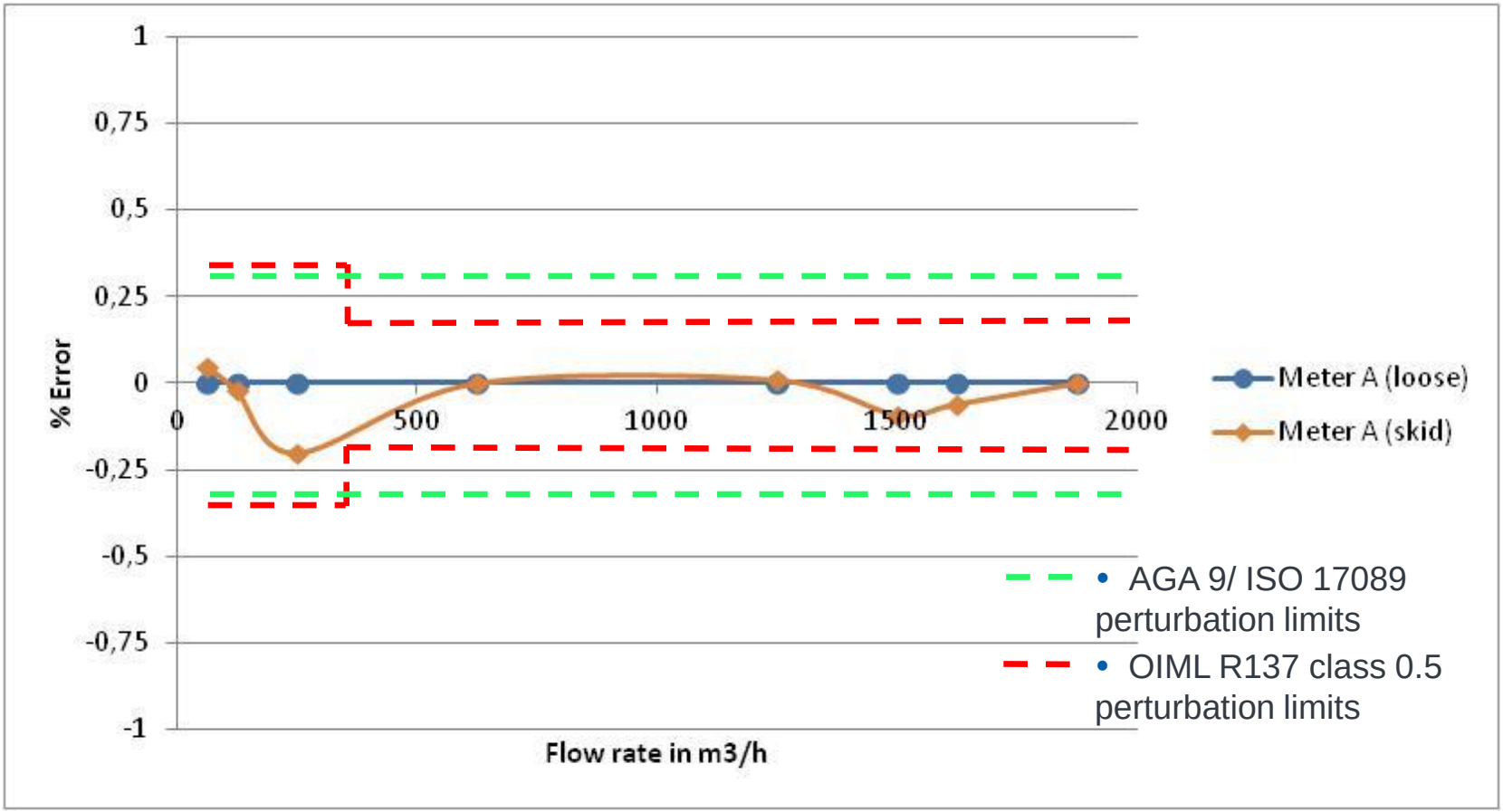
Flow profile meter A

Loose meter vs meter in skid at 1500 m3/h

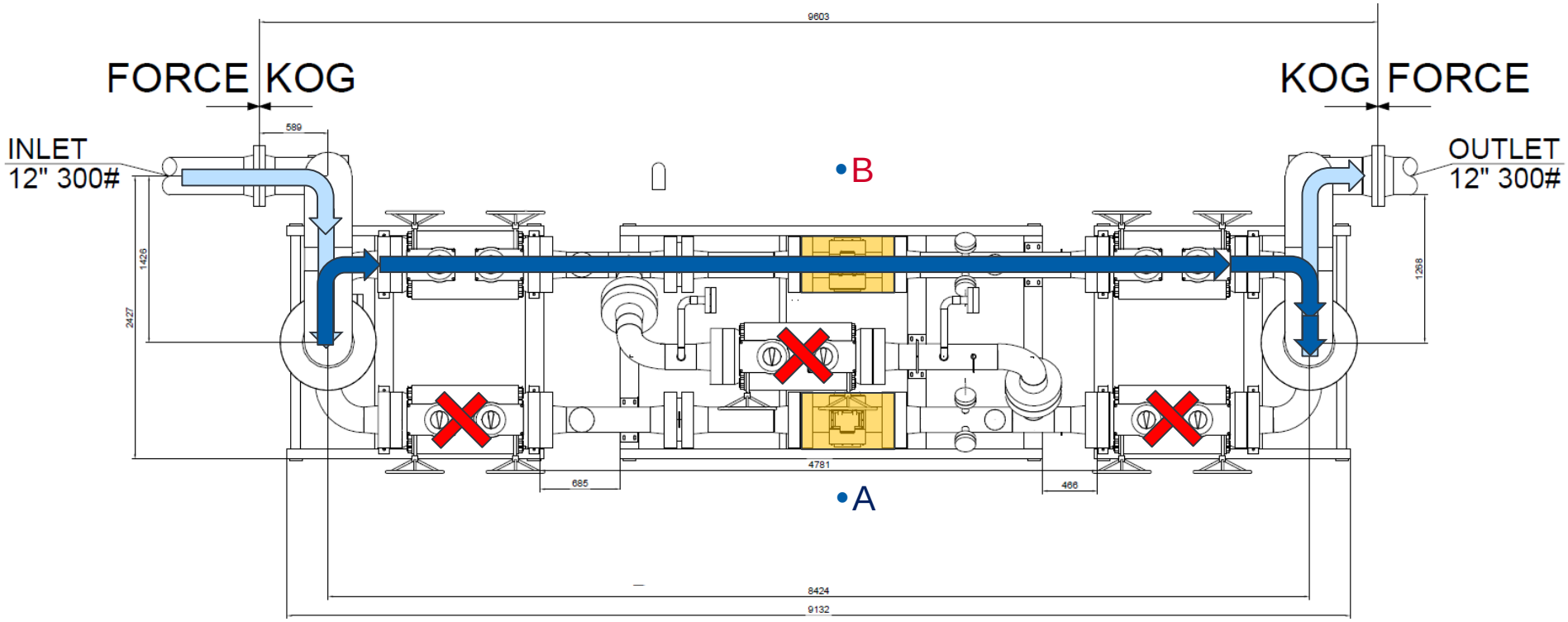


Calibration results meter A

Loose meter vs meter in skid



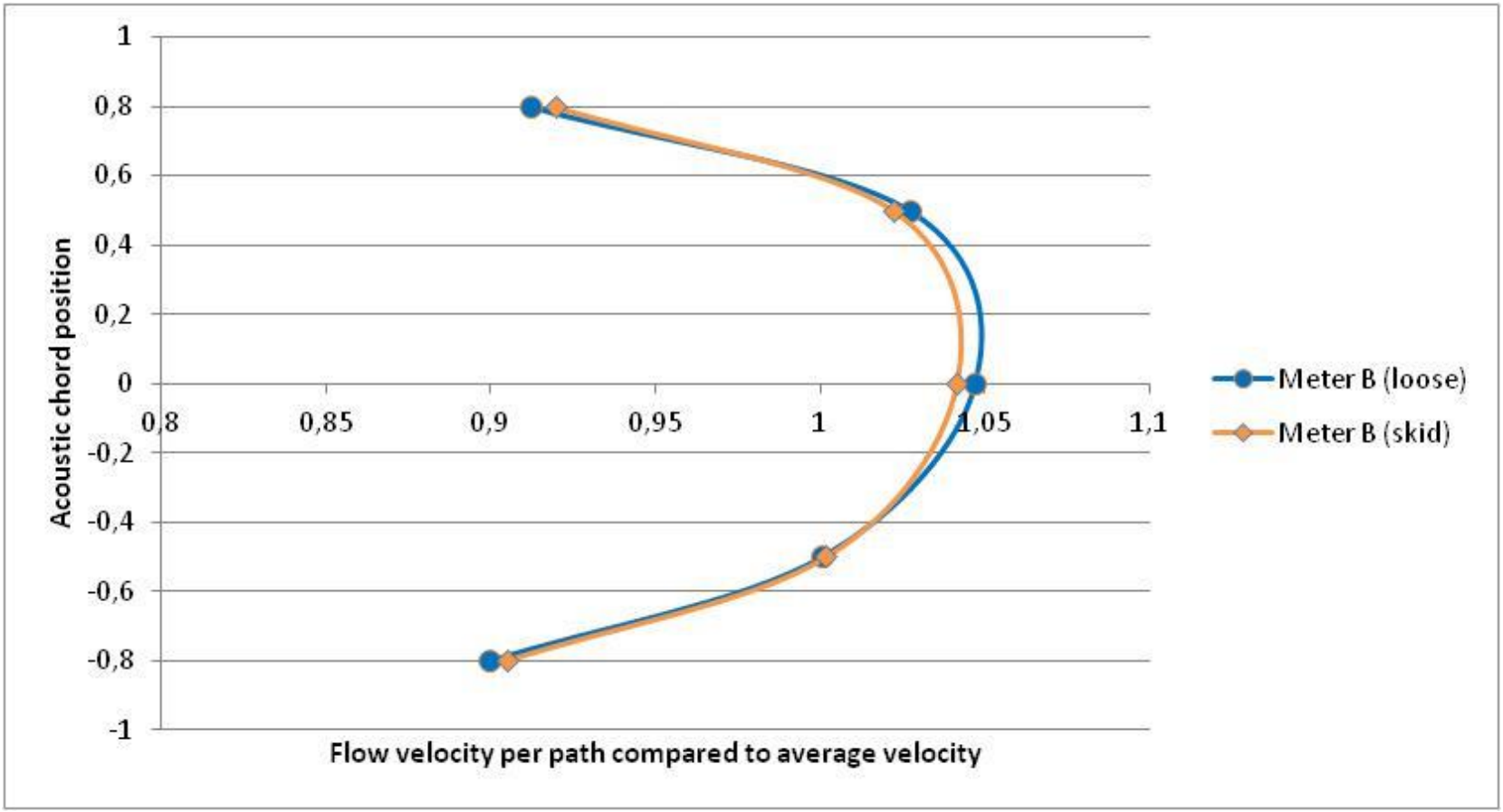
Calibration of meter B in skid



- Inlet conditions meter B:
  - 3x 90° bend, 1x T-section, 1x 90° bend (all swirl generators)
  - 2 fully open ball valves, 6D straight
  - Flow conditioner, 5D straight (used in original meter calibration)

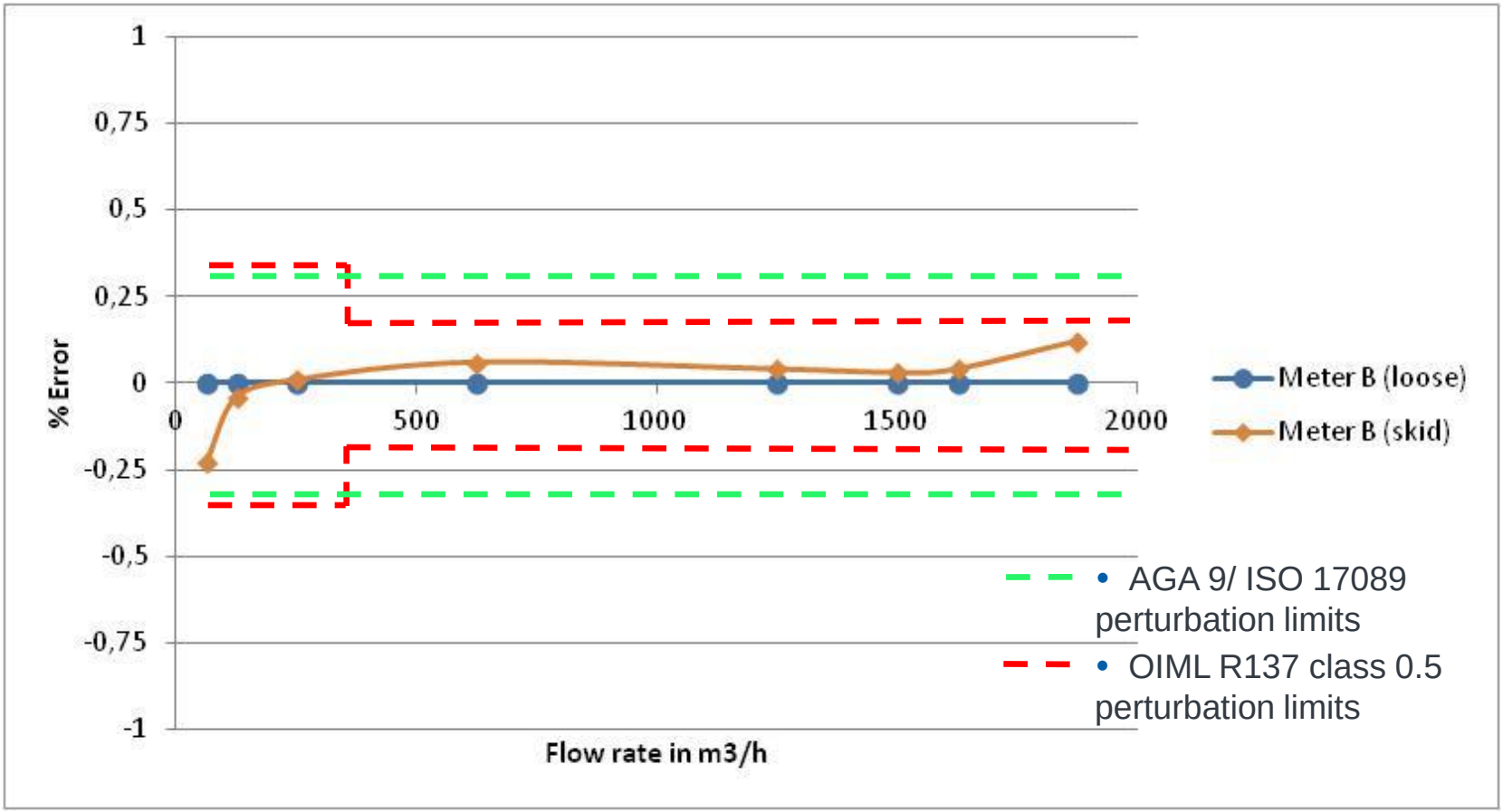
Flow profile meter B

Loose meter vs meter in skid at 1500 m3/h

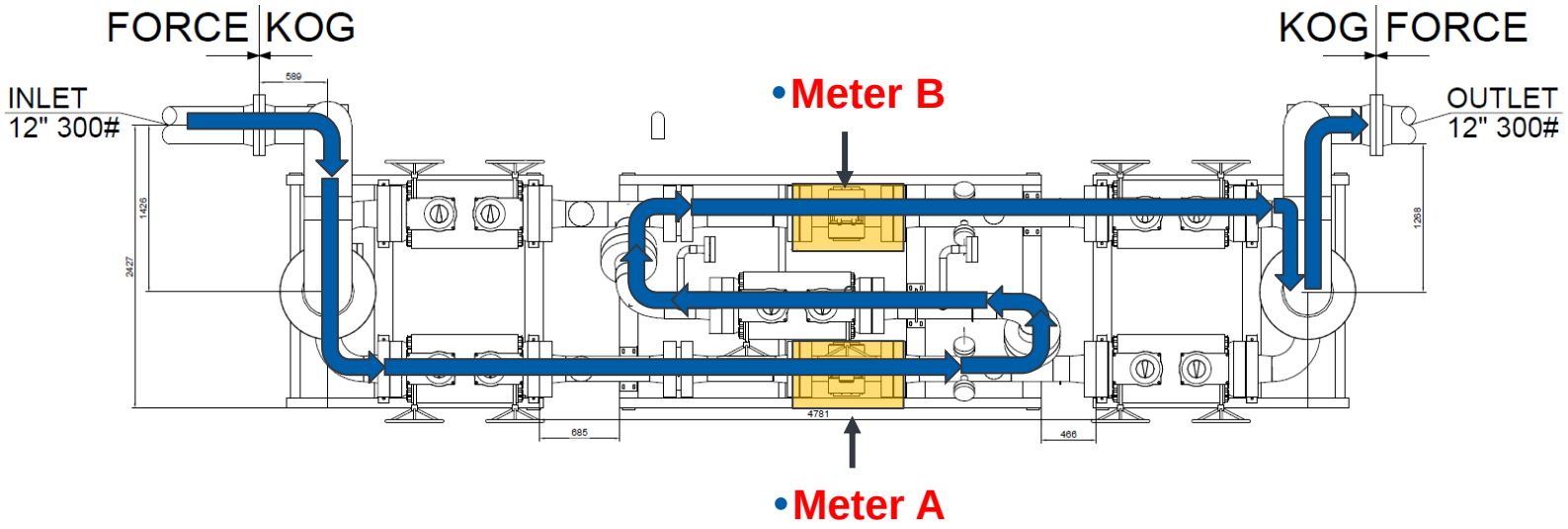


Calibration results meter B

Loose meter vs meter in skid



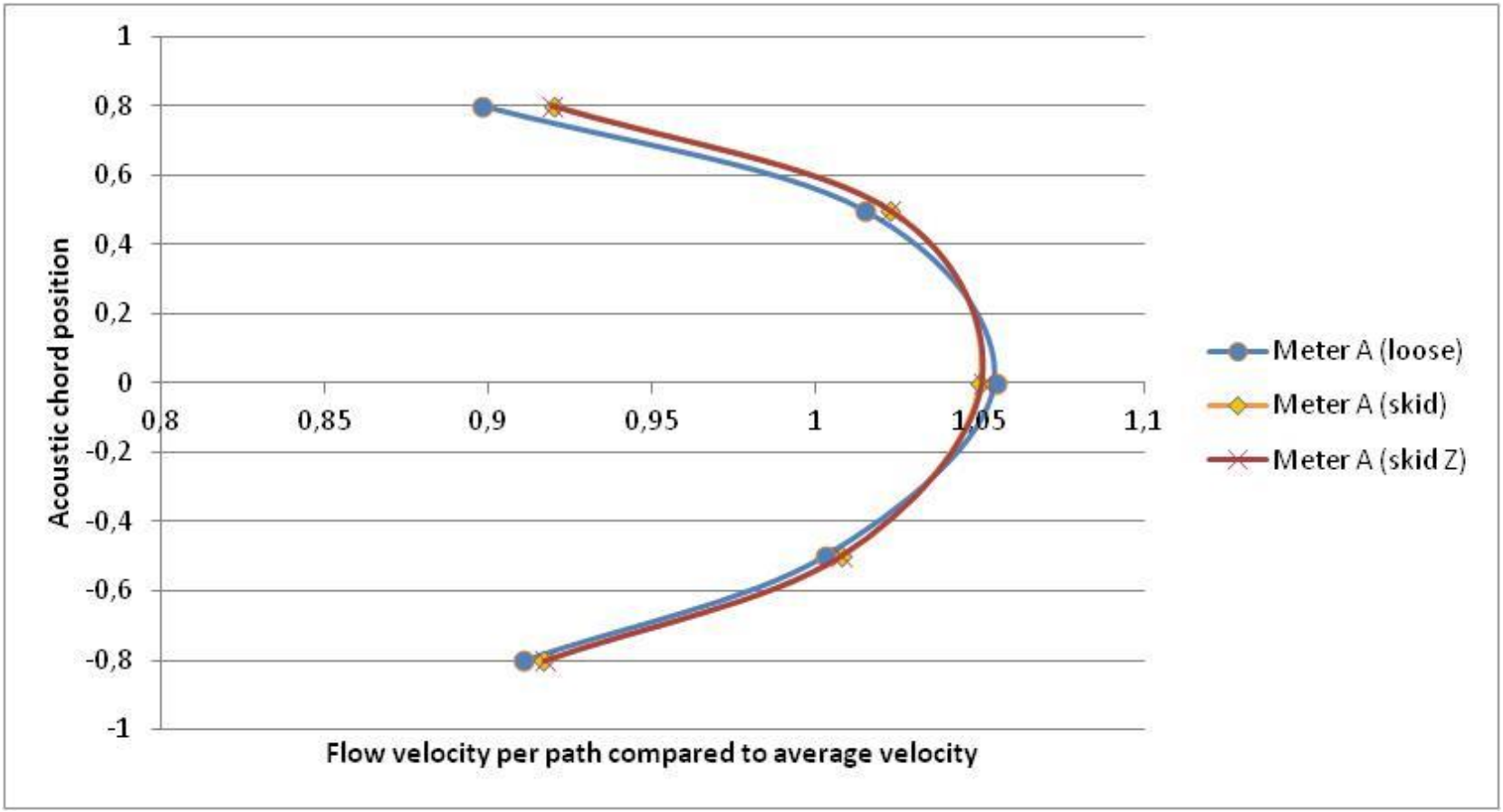
Calibration of meter A and B in skid



- Inlet conditions meter A:
  - 3x 90° bend, 1x T-section, 1x 90° bend (all swirl generators)
  - 2 fully open ball valves, 6D straight
  - Flow conditioner, 5D straight (used in original meter calibration)

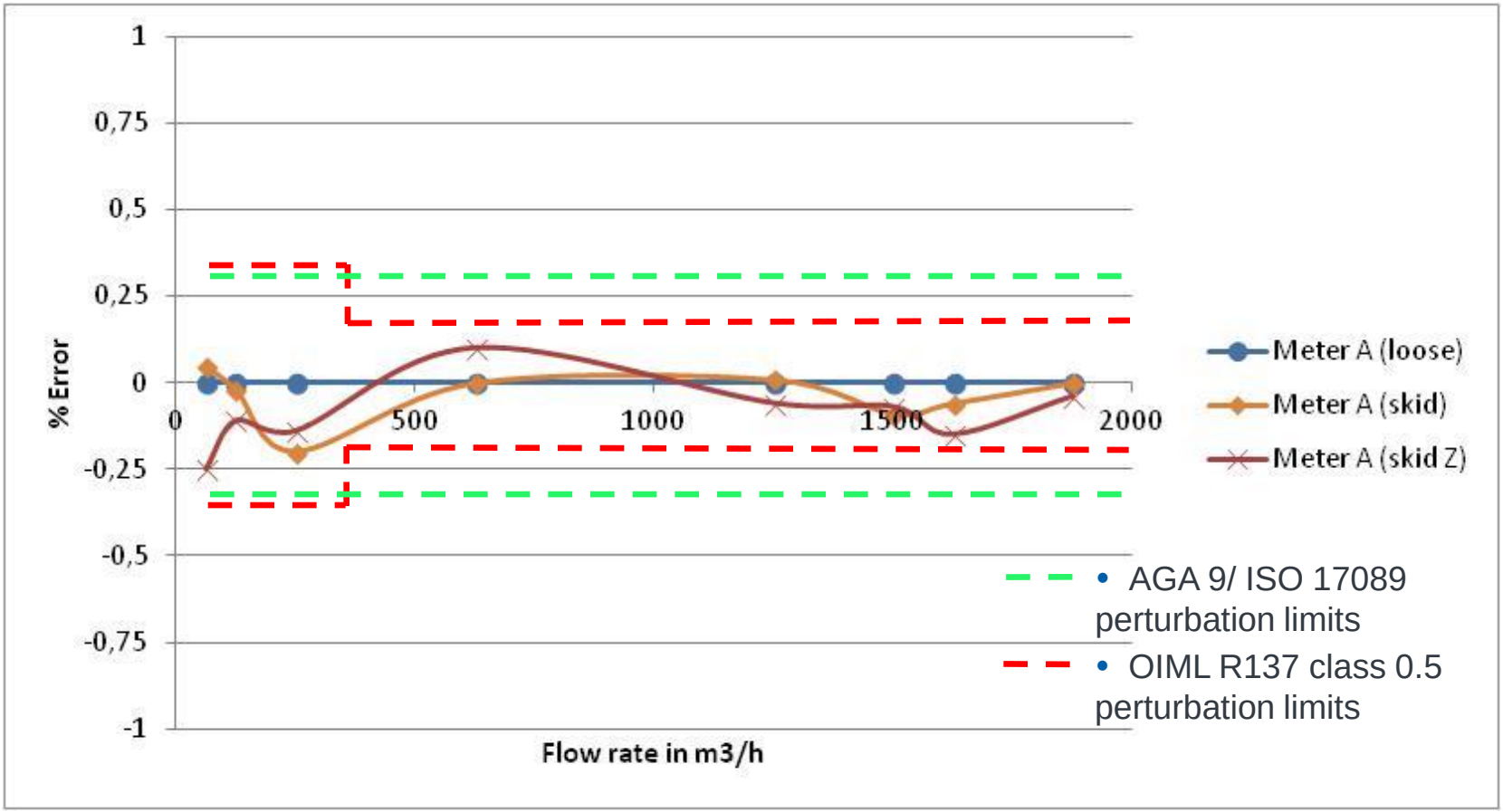
Flow profile meter A at 1500 m3/h

Loose meter vs meter in skid in Z-configuration

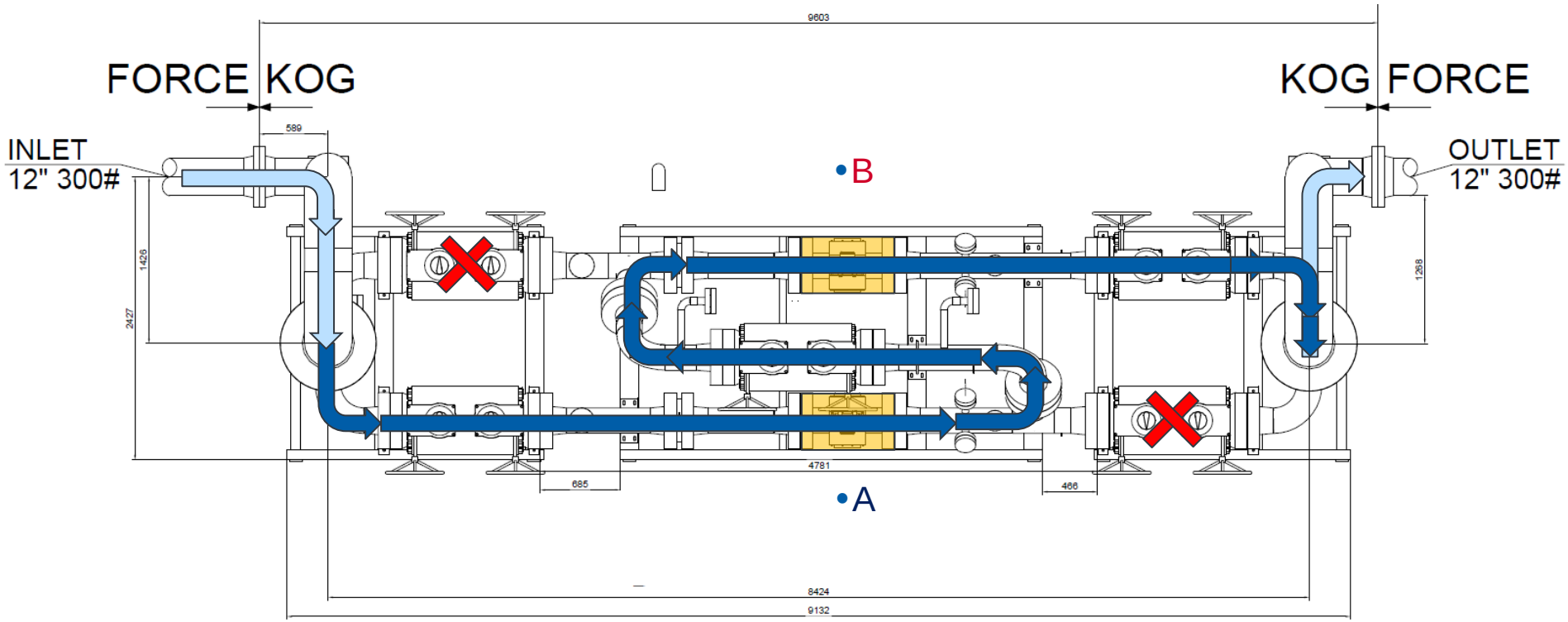


Calibration results meter A

Skid in parallel vs Z



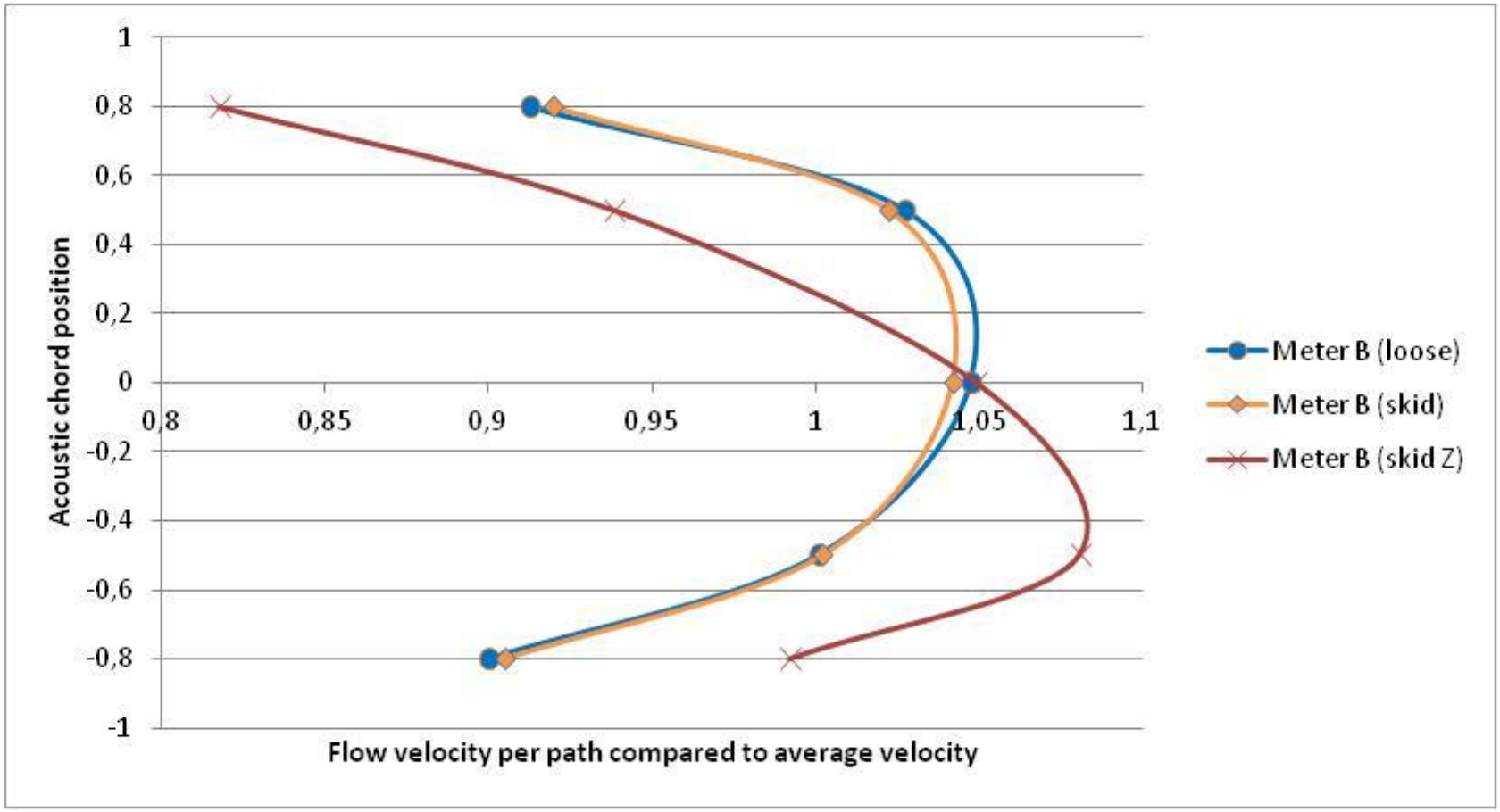
Calibration of meter A and B in skid



- Inlet conditions meter B:
  - 3x 90° bend, 1x T-section, 1x 90° bend (all swirl generators)
  - 2 fully open ball valves, 6D straight, flow conditioner, 15D straight
  - 1x T-section, 2x 90° bend, 1x T-section, 1D straight
  - Flow conditioner, 5D straight (used in original meter calibration)

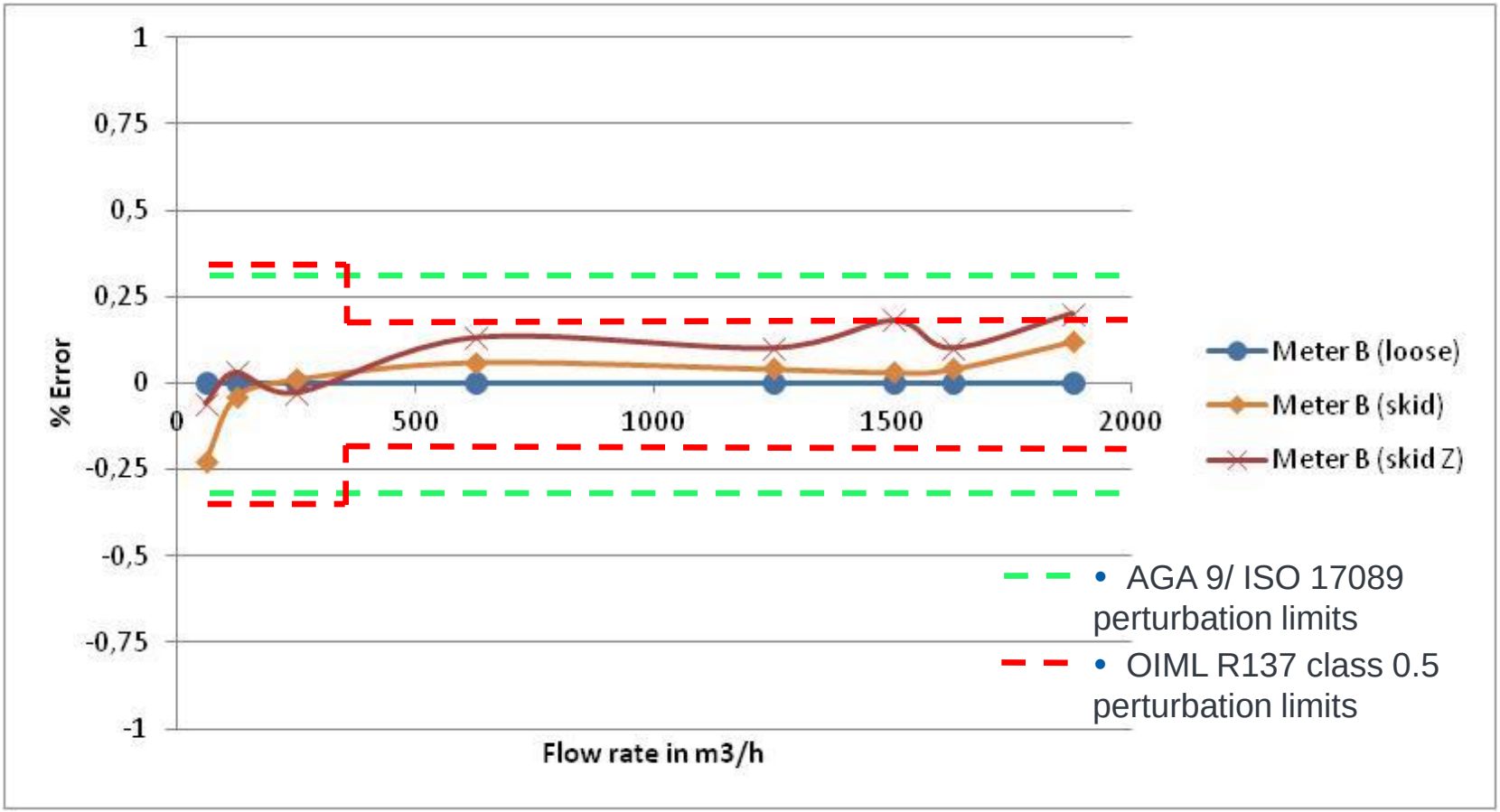
Flow profile meter B at 1500 m3/h

Loose meter vs meter in skid in Z-configuration



Calibration results meter B

Skid in parallel vs Z



Summary and conclusions

- Due to overall length restrictions meter B in Z-mode only had 1D straight inlet (settling chamber) upstream of the flow conditioner, less then the required 2D.
    - Despite the 1D settling chamber and significant perturbations all shift where well within AGA9 and ISO 17089 perturbation limits of ± 0.3%.
    - All results, except the highest flow rate of meter B in Z-mode, were within the OIML R137 class 0.5 perturbation limits of ± 0.17%. The modulations based on the log files afterwards indicate a 1.4D settling chamber was required. So it is expected that with a 2D settling chamber also meter B in Z-mode would have been within the severe limits.
- Different flow profiles do not automatically mean bad results, if you can recognize them.

Summary and conclusions

- It is possible to calibrate a complete skid but even for a small skid is it a lot of work.
    - Especially if the recalibration periods are short in the laws of the country.
- Z-configuration skids are perfectly possible with ultrasonic flowmeters.
- Calibrating result of meters remains valid when meters are placed in a skid, this means that there is no need to (re-)calibrate entire skids.
    - Loose meters including upstream conditions seem sufficient.
- It would be interesting to do the same test without flow conditioners to see if results would be similar.
    - But… we would need a new customer with a special request!

- To be continued…

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Thank you for your attention!